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J. McKEEN CATTELL

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THE MECHANISTIC CONCEPTION OF LIFE[1]

BY JACQUES LOEB
ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

1. Introductory

THE reader is aware that two conflicting conceptions are held in regard to the nature of life, namely, a vitalistic and a mechanistic. The vitalists deny the possibility of a complete explanation of life in terms of physics and chemistry. The mechanists proceed as though a complete and unequivocal physico-chemical analysis of life were the attainable goal of biology. It should also be stated that whenever a vitalist desires to make a contribution to science which is more substantial and lasting than mere argument or metaphor, he forgets or lays aside his vitalism and proceeds on the premises and methods of the mechanist. It is thus obvious that as far as the progress of biology is concerned the difference of viewpoint between vitalists and mechanists is of no consequence.

The difference between the two opposite views becomes only of importance when the results of biology are applied to ethical and sociological problems. Since applications of this kind present themselves constantly, the biologist may be pardoned if he raises the question whether or not our present state of knowledge justifies the expectation that life phenomena may ultimately be completely explained in terms of physics and chemistry. I intend to put before you a brief survey of some results, in the main recent, of scientific inquiry which I think may be utilized for an answer to this question.

Before going into these data, it may be necessary to allude briefly to a not uncommon misapprehension in regard to the nature of biological "truth" and methods. It is seemingly often taken for granted

[1] Address delivered at the First International Congress of Monists at Hamburg, September 10, 1911.

by laymen that "truth" in biology or science in general is of the same order as "truth" in certain of the mental sciences; that is to say, that everything rests on argument or rhetoric and that what is regarded as true to-day may be expected with some probability to be considered untrue to-morrow. It happens in science, especially in the descriptive sciences like paleontology or zoology, that hypotheses are forwarded, discussed and then abandoned. It should, however, be remembered that modern biology is fundamentally an experimental and not a descriptive science; and that its results are not rhetorical, but always assume one of two forms: it is either possible to control a life phenomenon to such an extent that we can produce it at desire at any time (as, *e. g.*, the contraction of an excised muscle); or we succeed in finding the numerical relation between the conditions of the experiment and the biological result (*e. g.*, Mendel's law of heredity). Biology as far as it is based on these two principles can not retrogress, but must advance.

2. The Beginning of Scientific Biology

Scientific biology, defined in this sense, begins with the attempt made by Lavoisier and Laplace (1780) to show that the quantity of heat which is formed in the body of a warm-blooded animal is equal to that formed in a candle, provided that the quantities of carbon dioxide formed in both cases are identical. This was the first attempt to reduce a life-phenomenon, namely, the formation of animal heat, completely to physico-chemical terms. What these two investigators began with primitive means has been completed by more recent investigators—Pettenkofer and Voit, Rubner and Zuntz. The oxidation of a food-stuff always furnishes the same amount of heat, no matter whether it takes place in the living body or outside.

These investigations left a gap. The substances which undergo oxidations in the animal body—starch, fat and proteins—are substances which at ordinary temperature are not easily oxidized. They require the temperature of the flame in order to undergo rapid oxidation through the oxygen of the air. This discrepancy between the oxidations in the living body and those in the laboratory manifests itself also in other chemical processes, *e. g.*, digestion or hydrolytic reactions, which were at first found to occur outside the living body rapidly only under conditions incompatible with life. This discrepancy was done away with by the physical chemists, who demonstrated that the same acceleration of chemical reactions which is brought about by a high temperature can also be accomplished at a low temperature with the aid of certain specific substances, the so-called catalyzers. This progress is connected preeminently with the names of Berzelius and Wilhelm Ostwald. The specific substances which accelerate the oxidations at

body temperature sufficiently to allow the maintenance of life are the so-called ferments of oxidation.

The work of Lavoisier and Laplace not only marks the beginning of scientific biology, it also touches the core of the problem of life; for it seems that oxidations form a part, if not the basis, of all life phenomena in higher organisms.

3. The "Riddle of Life"

By the "riddle of life" not everybody will understand the same thing. We all, however, desire to know how life originates and what death is, since our ethics must be influenced to a large extent through the answer to this question. We are not yet able to give an answer to the question as to how life originated on the earth. We know that every living being is able to transform food-stuffs into living matter; and we also know that not only the compounds which are formed in the animal body can be produced artificially, but that chemical reactions which take place in living organisms can also be repeated at the same rate and temperature in the laboratory. The gap in our knowledge which we feel most keenly is the fact that the chemical character of the catalyzers (the enzymes or ferments) is still unknown. Nothing indicates, however, at present that the artificial production of living matter is beyond the possibilities of science.

This view does not stand in opposition to the idea of Arrhenius that germs of sufficiently small dimensions are driven by radiation-pressure through space; and that these germs if they fall upon new cosmic bodies possessing water, salts and oxygen and the proper temperature, give rise to a new evolution of organisms. Biology will certainly retain this idea, but I believe that we must also follow out the other problem: namely, either succeed in producing living matter artificially, or find the reasons why this should be impossible.

4. The Activation of the Egg

Although we are not yet able to state how life originated in general, another, more modest problem has been solved, that is, how the egg is caused by the sperm to develop into a new individual. Every animal originates from an egg and in the majority of animals a new individual can only then develop if a male sex-cell, a spermatozoon, enters into the egg. The question as to how a spermatozoon can cause an egg to develop into a new individual was twelve years ago still shrouded in that mystery which to-day surrounds the origin of life in general. But to-day we are able to state that the problem of the activation of the egg is for the most part reduced to physico-chemical terms. The egg is in the unfertilized condition a single cell with only one nucleus.

If no spermatozoon enters into it, it perishes after a comparatively short time, in some animals in a few hours, in others in a few days or weeks. If, however, a spermatozoon enters into the egg, the latter begins to develop, *i. e.*, the nucleus begins to divide into two nuclei and the egg which heretofore consisted of one cell is divided into two cells. Subsequently each nucleus and each cell divides again into two, and so on. These cells have in many eggs the tendency to remain at the surface of the egg or to creep to the surface and later such an egg forms a hollow sphere whose shell consists of a large number of cells. On the outer surface of this hollow sphere cilia are formed and the egg is now transformed into a free-swimming larva. Then an intestine develops through the growing in of cells in one region of the blastula and gradually the other organs, skeleton, vascular system, etc., originate. Embryologists had noticed that occasionally the unfertilized eggs of certain animals, *e. g.*, sea-urchins, worms, or even birds, show a tendency to a nuclear or even a cell division; and R. Hertwig, Mead and Morgan had succeeded in inducing one or more cell divisions artificially in such eggs. But the cell divisions in these cases never led to the development of a larva, but at the best to the formation of an abnormal mass of cells which soon perished.

I succeeded twelve years ago in causing the unfertilized eggs of the sea-urchin to develop into swimming larvæ by treating them with sea-water, the concentration of which was raised through the addition of a small but definite quantity of a salt or sugar. The eggs were put for two hours into a solution the osmotic pressure of which had been raised to a certain height. When the eggs were put back into normal sea-water they developed into larvæ and a part of these larvæ formed an intestine and a skeleton. The same result was obtained in the eggs of other animals, starfish, worms and mollusks. These experiments proved the possibility of substituting physico-chemical agencies for the action of the living spermatozoon, but did not yet explain how the spermatozoon causes the development of the egg, since in these experiments the action of the spermatozoon upon the egg was very incompletely imitated. When a spermatozoon enters into the egg it causes primarily a change in the surface of the egg which results in the formation of the so-called membrane of fertilization. This phenomenon of membrane formation which had always been considered as a phenomenon of minor importance did not occur in my original method of treating the egg with hypertonic sea-water. Six years ago while experimenting on the Californian sea-urchin, *Strongylocentrotus purpuratus*, I succeeded in finding a method of causing the unfertilized egg to form a membrane without injuring the egg. This method consists in treating the eggs for from one to two minutes with sea-water

to which a definite amount of butyric acid (or some other monobasic fatty acid) has been added. If after that time the eggs are brought back into normal sea-water, all form a fertilization membrane in exactly the same way as if a spermatozoon had entered. This membrane formation or rather the modification of the surface of the egg which underlies the membrane formation starts the development. It does not allow it, however, to go very far at room temperature. In order to allow the development to go further it is necessary to submit the eggs after the butyric acid treatment to a second operation. Here we have a choice between two methods. We can either put the eggs for about one half hour into a hypertonic solution (which contains free oxygen); or we can put them for about three hours into sea-water deprived of oxygen. If the eggs are then returned to normal sea-water containing oxygen they all develop; and in a large number the development is as normal as if a spermatozoon had entered.

The essential feature is therefore the fact that the development is caused by two different treatments of the egg; and that among these the treatment resulting in the formation of the membrane is the more important one. This is proved by the fact that in certain forms, as for instance the star-fish, the causation of the artificial membrane formation may suffice for the development of normal larvæ; although here too the second treatment increases not only the number of larvæ, but also improves the appearance of the larvæ, as R. Lillie found.

The question now arises, how the membrane formation can start the development of the egg. An analysis of the process and of the nature of the agencies which cause it yielded the result that the unfertilized egg possesses a superficial cortical layer, which must be destroyed before the egg can develop. It is immaterial by what means this superficial cortical layer is destroyed. All agencies, which cause a definite type of cell destruction—the so-called cytolysis—cause also the egg to develop, as long as their action is limited to the surface layer of the cell. The butyric acid treatment of the egg mentioned above only serves to induce the destruction of this cortical layer. In the eggs of some animals this cortical layer can be destroyed mechanically by shaking the egg, as A. P. Mathews found in the case of star-fish eggs and I in the case of the eggs of certain worms. In the case of the eggs of the frog it suffices to pierce the cortical layer with a needle, as Bataillon found in his beautiful experiments a year ago.[2] The mechanism by which development is caused is apparently the same in all these cases, namely, the destruction of the cortical layer of the eggs. This can be caused generally by certain chemical means which play a

[2] This method does not work with the eggs of fish and is apparently as limited in its applicability as the causation of development by mechanical agitation.

rôle also in bacteriology; but it can also be caused in special cases by mechanical means, such as agitation or piercing of the cortical layer. It may be mentioned parenthetically that foreign blood sera have also a cytolytic effect, and I succeeded in causing membrane formation and in consequence the development of the sea-urchin egg by treating it with the blood of various animals, *e. g.*, of cattle, or the rabbit.

Recently Shearer has succeeded in Plymouth in causing a number of parthenogenetic plutei produced by my method to develop beyond the stage of metamorphosis, and Delage has reported that he raised two larvæ of the sea-urchin produced by artificial parthenogenesis to the stage of sexual maturity. We may, therefore, state that the complete imitation of the developmental effect of the spermatozoon by certain physico-chemical agencies has been accomplished.

I succeeded in showing that the spermatozoon causes the development of the sea-urchin egg in a way similar to that in my method of artificial parthenogenesis; namely, by carrying two substances into the egg, one of which acts like the butyric acid and induces the membrane formation, while the other acts like the treatment with a hypertonic solution and enables the full development of the larvæ. In order to prove this for the sea-urchin egg foreign sperm, *e. g.*, that of the starfish, must be used. The sperm of the sea-urchin penetrates so rapidly into the sea-urchin egg that almost always both substances get into the egg. If, however, star-fish sperm is used for the fertilization of the sea-urchin egg, in a large number of cases, membrane formation occurs before the spermatozoon has found time to entirely penetrate into the egg. In consequence of the membrane formation the spermatozoon is thrown out. Such eggs behave as if only the membrane formation had been caused by some artificial agency, *e. g.*, butyric acid. They begin to develop, but soon show signs of disintegration. If treated with a hypertonic solution they develop into larvæ. In touching the egg contents the spermatozoon had a chance to give off a substance which liquefied the cortical layer and thereby caused the membrane formation by which the further entrance of the spermatozoon into the egg was prevented. If, however, the starfish sperm enters completely into the egg before the membrane formation begins, the spermatozoon carries also the second substance into the egg, the action of which corresponds to the treatment of the egg with the hypertonic solution. In this case the egg can undergo complete development into a larva.

F. Lillie has recently confirmed the same fact in the egg of a worm, *Nereis*. He mixed the sperm and eggs of *Nereis* and centrifuged the mass. In many cases the spermatozoa which had begun to penetrate into the egg were thrown off again. The consequence was that only a membrane formation resulted without the spermatozoon penetrating

into the egg. This membrane formation led only to a beginning but not to a complete development. We may, therefore, conclude that the spermatozoon causes the development of the egg in a way similar to that which takes place in the case of artificial parthenogenesis. It carries first a substance into the egg which destroys the cortical layer of the egg in the same way as butyric acid does; and secondly a substance which corresponds in its effect to the influence of the hypertonic solution in the sea-urchin egg after the membrane formation.

The question arises as to how the destruction of the cortical layer can cause the beginning of the development of the egg. This question leads us to the process of oxidation. Years ago I had found that the fertilized sea-urchin egg can only develop in the presence of free oxygen; if the oxygen is completely withdrawn the development stops, but begins again promptly as soon as oxygen is again admitted. From this and similar experiments I concluded that the spermatozoon causes the development by accelerating the oxidations in the egg. This conclusion was confirmed by experiments by O. Warburg and by Wasteneys and myself in which it was found that through the process of fertilization the velocity of oxidations in the egg is increased to four or six times its original value. Warburg was able to show that the mere causation of the membrane formation by the butyric acid treatment has the same accelerating effect upon the oxidations as fertilization.

What remains unknown at present is the way in which the destruction of the cortical layer of the egg accelerates the oxidations. It is possible that the cortical layer acts like a solid crust and thus prevents the oxygen from reaching the surface of the egg or from penetrating into the latter sufficiently rapidly. The solution of these problems must be reserved for further investigation.

We, therefore, see that the process of the activation of the egg by the spermatozoon, which twelve years ago was shrouded in complete darkness, to-day is practically completely reduced to a physico-chemical explanation. Considering the youth of experimental biology we have a right to hope that what has been accomplished in this problem will occur in rapid succession in those problems which to-day still appear as riddles.

5. Nature of Life and Death

The nature of life and of death are questions which occupy the interest of the layman to a greater extent than possibly any other purely theoretical problem; and we can well understand that humanity did not wait for experimental biology to furnish an answer. The answer assumed the anthropomorphic form characteristic of all explanations of nature in the prescientific period. Life was assumed to begin with the entrance of a "life principle" into the body; that individual life be-

gins with the egg was of course unknown to primitive or pre-scientific man. Death was assumed to be due to the departure of this "life principle" from the body.

Scientifically, however, individual life begins (in the case of the sea-urchin and possibly in general) with the acceleration of the rate of oxidation in the egg, and this acceleration begins after the destruction of its cortical layer. Life of warm blooded animals—man included—ends with the cessation of oxidation in the body. As soon as oxidations have ceased for some time the surface films of the cells, if they contain enough water and if the temperature is sufficiently high, become permeable for bacteria, and the body is destroyed by microorganisms. The problem of the beginning and end of individual life is physico-chemically clear. It is, therefore, unwarranted to continue the statement that in addition to the acceleration of oxidations the beginning of individual life is determined by the entrance of a metaphysical "life principle" into the egg; and that death is determined, aside from the cessation of oxidations, by the departure of this "principle" from the body. In the case of the evaporation of water we are satisfied with the explanation given by the kinetic theory of gases and do not demand that—to repeat a well-known jest of Huxley—the disappearance of the "aquosity" be also taken into consideration.

6. Heredity

It may be stated that the egg is the essential bearer of heredity. We can cause an egg to develop into a larva without sperm, but we can not cause a spermatozoon to develop into a larva without an egg. The spermatozoon can influence the form of the offspring only when the two forms are rather closely related. If the egg of a sea-urchin is fertilized with the sperm from a different species of sea-urchin the larval form has distinct paternal characters. If, however, the eggs of a sea-urchin are fertilized with the sperm of a more remote species, *e. g.*, a star-fish, the result is a sea-urchin larva which possesses no paternal characters, as I found and as Godlewski, Kupelwieser, Hagedoorn and Baltzer were able to confirm. This fact has some bearing upon the further investigation of heredity, inasmuch as it shows that the egg is the main instrument of heredity, while apparently the spermatozoon is restricted in the transmission of characters to the offspring. If the difference between spermatozoon and egg exceeds a certain limit the hereditary effects of the spermatozoon cease and it acts merely as an activator to the egg.

As far as the transmission of paternal characters is concerned, we can say to-day that the view of those authors was correct who, with Boveri, localized this transmission not only in the cell nucleus, but in a

special constituent of the nucleus, the chromosomes. The proof for this was given by facts found along the lines of Mendelian investigations. The essential law of Mendel, the law of segregation, can in its simplest form be expressed in the following way. If we cross two forms which differ in only one character every hybrid resulting from this union forms two kinds of sex-cells in equal numbers; two kinds of eggs if it is a female, two kinds of spermatozoa if it is a male. The one kind corresponds to the pure paternal, the other to the pure maternal type. The investigation of the structure and behavior of the nucleus showed that the possibility for such a segregation of the sex-cells in a hybrid can easily be recognized during a given stage in the formation of the sex-cells, if the assumption is made that the chromosomes are the bearers of the paternal characters. The proof for the correctness of this view was furnished through the investigation of the heredity of those qualities which occur mainly in one sex; *e. g.*, color blindness which occurs preeminently in the male members of a family.

Nine years ago McClung published a paper which solved the problem of sex determination, at least in its essential feature. Each animal has a definite number of chromosomes in its cell nucleus. Henking had found that in a certain form of insects (*Pyrrhocoris*) two kinds of spermatozoa exist which differ in the fact that the one possesses a nucleolus while the other does not. Montgomery afterwards showed that Henking's nucleolus was an accessory chromosome. McClung first expressed the idea that this accessory chromosome was connected with the determination of sex. Considering the importance of this idea we may render it in his own words:

> A most significant fact, and one upon which almost all investigators are united in opinion, is that the element is apportioned to but one half of the spermatozoa. Assuming it to be true that the chromatin is the important part of the cell in the matter of heredity, then it follows that we have two kinds of spermatozoa that differ from each other in a vital matter. We expect, therefore, to find in the offspring two sorts of individuals in approximately equal numbers, under normal conditions, that exhibit marked differences in structure. A careful consideration will suggest that nothing but sexual characters thus divides the members of a species into two well-defined groups, and we are logically forced to the conclusion that the peculiar chromosome has some bearing upon the arrangement.
>
> I must here also point out a fact that does not seem to have the recognition it deserves; viz., that if there is a cross division of the chromosomes in the maturation mitoses, there must be two kinds of spermatozoa regardless of the presence of the accessory chromosome. It is thus possible that even in the absence of any specialized element a preponderant maleness would attach to one half of the spermatozoa, due to the "qualitative division of the tetrads."

The researches of the following years, especially the brilliant work of E. B. Wilson, Miss Stevens, T. H. Morgan and others, have amply confirmed the correctness of this ingenious idea and cleared up the problem of sex determination in its main features.

According to McClung each animal forms two kinds of spermatozoa in equal numbers, which differ by one chromosome. One kind of spermatozoa produces male animals, the other female animals. The eggs are all equal in these animals. More recent investigations, especially by E. B. Wilson, have shown that this view is correct for many animals.

While in many animals there are two kinds of spermatozoa and only one kind of eggs, in other animals two kinds of eggs and only one kind of spermatozoa are formed, *e. g.*, sea-urchins and certain species of birds and of butterflies (*Abraxas*). In these animals the sex is predetermined in the egg and not in the spermatozoon. It is of interest that, according to Guyer, in the human being two kinds of spermatozoa exist and only one kind of eggs; in man, therefore, sex is determined by the spermatozoon.

How is sex determination accomplished? Let us take the case which according to Wilson is true for many insects and according to Guyer for human beings, namely, that there are two kinds of spermatozoa and one kind of egg. According to Wilson all unfertilized eggs contain in this case one so-called sex chromosome, the X-chromosome. There are two kinds of spermatozoa, one with and one without an X-chromosome. Given a sufficiently large number of eggs and of spermatozoa, one half of the egs will be fertilized by spermatozoa with and one half by spermatozoa without an X-chromosome. Hence one half of the eggs will contain *after* fertilization two X-chromosomes each and one half only one X-chromosome each. The eggs containing only one X-chromosome give rise to males, those containing two X-chromosomes give rise to females—as Wilson and others have proved. This seems to be a general law for those cases in which there are two kinds of spermatozoa and one kind of eggs.

These observations show why it is impossible to influence the sex of a developing embryo by external influences. If, for example, in the human a spermatozoon without an X-chromosome enters into an egg, the egg will give rise to a boy, but if a spermatozoon with an X-chromosome gets into the egg the latter will give rise to a girl. Since always both kinds of spermatozoa are given off by the male it is a mere matter of chance whether a boy or a girl originates; and it agrees with the law of probability that in a large population the number of boys and girls borne within a year is approximately the same.

These discoveries solved also a series of other difficulties. Certain types of twins originate from one egg after fertilization. Such twins have always the same sex, as we should expect since the cells of both twins have the same number of X-chromosomes.

In plant lice, bees and ants, the eggs may develop with and without

fertilization. It was known that from fertilized eggs in these animals only females develop, males never. It was found that in these animals the eggs contain only one sex-chromosome; while in the male are found two kinds of spermatozoa, one with and one without a sex-chromosome. For *Phylloxera* and *Aphides* it has been proved with certainty by Morgan and others that the spermatozoa which contain no sex-chromosome can not live, and the same is probably true for bees and ants. If, therefore, in these animals an egg is fertilized it is always done by a spermatozoon which contains an *X*-chromosome. The egg has, therefore, after fertilization in these animals always two *X*-chromosomes and from such eggs only females can arise.

It had been known for a long time that in bees and ants the unfertilized eggs can also develop, but such eggs give rise to males only. This is due to the fact that the eggs of these animals contain only one *X*-chromosome and from eggs with only one chromosome only males can arise (at least in the case of animals in which the male is heterozygous for sex).

The problem of sex determination has, therefore, found a simple solution, and simultaneously Mendel's law of segregation finds also its solution.

In many insects and in man the cells of the female have two sex-chromosomes. In a certain stage of the history of the egg one half of the chromosomes leaves the egg (in the form of the "polar-body") and the egg keeps only half the number of chromosomes. Each egg, therefore, retains only one *X* or sex-chromosome. In the male the cells have from the beginning only one *X*-chromosome and each primordial spermatozoon divides into two new (in reality into two pairs of) spermatozoa, one of which contains an *X*-chromosome while the other is without such a chromosome. What can be observed here directly in the male animal takes place in every hybrid: during the critical, so-called maturation division of the sexual cell in the hybrid a division of the chromosomes occurs whereby only one half of the sex cells receive the hereditary substance in regard to which the two original pure forms differ.

That this is not a mere assumption can be shown in those cases in which the hereditary character appears only, or preeminently, in one sex as, *e. g.*, color blindness which appears mostly in the male. If a color-blind individual is mated with an individual with normal color vision the heredity of color blindness in the next two generations corresponds quantitatively with what we must expect on the assumption that the chemical substances determining color vision are contained in the sex-chromosomes. In the color-blind individual something is lacking which can be found in the individual with normal color perception. The factor for color vision is obviously transmitted through the sex-

chromosome. In the next generation color blindness can not appear since each fertilized egg contains the factor for color perception. In the second generation, however, the theory demands that one half of the males should be color blind. In man these conditions can not always be verified numerically since the number of children is too small to yield the conditions to be expected according to the calculus of probability. T. H. Morgan has found in a fly (*Drosophila*) a number of similar sex-limited characters, which behave like color blindness, *e. g.*, lack of pigment in the eyes. These flies have normally red eyes. Morgan has observed a mutation with white eyes, which occurs in the male. When he crossed a white-eyed with a red-eyed female all flies of the first generation were red-eyed; since all flies had the factor for pigment in their sex-cells; in the second generation all females and exactly one half of the males had red eyes, the other half of the males, however, white eyes, as the theory demands.

From these and numerous similar breeding experiments of Correns, Doncaster, and especially of Morgan, we may conclude with certainty that the sex-chromosomes are the bearers of those hereditary characters which appear preeminently in one sex. We say preeminently since theoretically we can predict cases in which color blindness or white eyes must appear also in the female. Breeding experiments have shown that this theoretical prediction is justified. The riddle of Mendel's law of segregation finds its solution by these experiments and incidentally also the problem of the determination of sex which is only a special case of the law of segregation, as Mendel already intimated.

The main task which is left here for science to accomplish is the determination of the chemical substances in the chromosomes which are responsible for the hereditary transmission of a quality, and the determination of the mechanism by which these substances give rise to the hereditary character. Here the ground has already been broken. It is known that for the formation of a certain black pigment the cooperation of a substance—tyrosin—and of a ferment of oxidation—tyrosinase—is required. The hereditary transmission of the black color through the male animal must occur by substances carried in the chromosome which determine the formation of tyrosin or tyrosinase or of both. We may, therefore, say that the solution of the riddle of heredity has succeeded to the extent that all further development will take place purely in cytological and physico-chemical terms.

While until twelve years ago the field of heredity was the stamping ground for the rhetorician and metaphysician it is to-day perhaps the most exact and rationalistic part of biology, where facts can not only be predicted qualitatively, but also quantitatively.

7. The Harmonious Character of the Organisms

It is not possible to prove in a short address that all life phenomena will yield to a physico-chemical analysis. We have selected only the phenomena of fertilization and heredity, since these phenomena are specific for living organisms and without analogues in inanimate nature; and if we can convince ourselves that these processes can be explained physico-chemically we may safely expect the same of such processes for which there exist *a priori* analogies in inanimate nature, as, *e. g.*, for absorption and secretion.

We must, however, settle a question which offers itself not only to the layman but also to every biologist, namely, how we shall conceive that wonderful "adaptation of each part to the whole" by which an organism becomes possible. In the answer of this question the metaphysician finds an opportunity to put above the purely chemical and physical processes something specific which is characteristic of life only: the "Zielstrebigkeit," the "harmony" of the phenomena, or the "dominants" of Reinke and similar things.

With all due personal respect for the authors of such terms I am of the opinion that we are dealing here, as in all cases of metaphysics, with a play on words. That a part is so constructed that it serves the "whole" is only an unclear expression for the fact that a species is only able to live—or to use Roux's expression—is only durable, if it is provided with the automatic mechanism for self-preservation and reproduction. If, for instance, warm-blooded animals should originate without a circulation they could not remain alive, and this is the reason why we never find such forms. The phenomena of "adaptation" cause only apparent difficulties since we rarely or never become aware of the numerous faultily constructed organisms which appear in nature. I will illustrate by a concrete example that the number of species which we observe is only an infinitely small fraction of those which can originate and possibly not rarely do originate, but which we never see since their organization does not allow them to exist long. Moenkhaus found ten years ago that it is possible to fertilize the egg of each marine bony fish with the sperm of practically any other marine bony fish. His embryos apparently lived only a very short time. This year I succeeded in keeping such hybrid embryos between distantly related bony fish alive for over a month. It is, therefore, clear that it is possible to cross practically any marine teleost with any other.

The number of teleosts at present in existence is about 10,000. If we accomplish all possible hybridization 100,000,000 different crosses will result. Of these teleosts only a very small proportion, namely about one one-hundredth of one per cent., can live. It turned out in my experiments that the heterogeneous hybrids between bony fishes formed

eyes, brains, ears, fins and pulsating hearts, blood and blood vessels, but could live only a limited time because no blood circulation was established at all—in spite of the fact that the heart beat for weeks—or that the circulation, if it was established at all, did not last long.

What prevented these heterogeneous fish embryos from reaching the adult stage? The lack of the proper "dominants"? Scarcely. I succeeded in producing the same type of faulty embryos in the pure breeds of a bony fish (*Fundulus heteroclitus*) by raising the eggs in 50 c.c. of sea-water to which was added 2 c.c. one one-hundredth per cent. NaCN. The latter substance retards the velocity of oxidations and I obtained embryos which were in all details identical with the embryos produced by crossing the eggs of the same fish with the sperm of remote teleosts, *e. g.*, *Ctenolabrus* or *Menidia*. These embryos, which lived about a month, showed the peculiarity of possessing a beating heart and blood, but no circulation. This suggests the idea that heterogeneous embryos show a lack of "adaptation" and durability for the reason that in consequence of the chemical difference between heterogeneous sperm and egg the chemical processes in the fertilized egg are abnormal.

The possibility of hybridization goes much further than we have thus far assumed. We can cause the eggs of echinoderms to develop with the sperm of very distant forms, even mollusks and worms (Kupelwieser); but such hybridizations never lead to the formation of durable organisms.

It is, therefore, no exaggeration to state that the number of species existing to-day is only an infinitely small fraction of those which can and possibly occasionally do originate, but which escape our notice because they can not live and reproduce. Only that limited fraction of species can exist which possesses no coarse disharmonies in its automatic mechanism of preservation and reproduction. Disharmonies and faulty attempts in nature are the rule, the harmonically developed systems the rare exception. But since we only perceive the latter we gain the erroneous impression that the "adaptation of the parts to the plan of the whole" is a general and specific characteristic of animate nature, whereby the latter differs from inanimate nature.

If the structure and the mechanism of the atoms were known to us we should probably also get an insight into a world of wonderful harmonies and apparent adaptations of the parts to the whole. But in this case we should quickly understand that the chemical elements are only the few durable systems among a large number of possible but not durable combinations. Nobody doubts that the durable chemical elements are only a product of blind forces. There is no reason for conceiving otherwise the durable systems in living nature.

8. The Contents of Life

The contents of life from the cradle to the bier are wishes and hopes, efforts and struggles and unfortunately also disappointments and suffering. And this inner life should be amenable to a physico-chemical analysis? In spite of the gap which separates us to-day from such an aim I believe that it is attainable. As long as a life phenomenon has not yet found a physico-chemical explanation it usually appears inexplicable. If the veil is once lifted we are always surprised that we did not guess from the first what was behind it.

That in the case of our inner life a physico-chemical explanation is not beyond the realm of possibility is proved by the fact that it is already possible for us to explain cases of simple manifestations of animal instinct and will on a physico-chemical basis; namely, the phenomena which I have discussed in former papers under the name of animal tropisms. As the most simple example we may mention the tendency of certain animals to fly or creep to the light. We are dealing in this case with the manifestation of an instinct or impulse which the animals can not resist. It appears as if this blind instinct which these animals must follow, although it may cost them their life might be explained by the same law of Bunsen and Roscoe, which explains the photo-chemical effects in inanimate nature. This law states that within wide limits the photo-chemical effect equals the product of the intensity of light into the duration of illumination. It is not possible to enter here into all the details of the reactions of these animals to light, we only wish to point out in which way the light instinct of the animals may possibly be connected with the Bunsen-Roscoe law.

The positively heliotropic animals—*i. e.,* the animals which go instinctively to a source of light—have in their eyes (and occasionally also in their skin) photosensitive substances which undergo chemical alterations by light. The products formed in this process influence the contraction of the muscles—mostly indirectly, through the central nervous system. If the animal is illuminated on one side only the mass of photochemical reaction products formed on that side in the unit of time is greater than on the opposite side. Consequently the development of energy in the symmetrical muscles on both sides of the body becomes unequal. As soon as the difference in the masses of the photochemical reaction products on both sides of the animal reaches a certain value the animal, as soon as it moves, is automatically forced to turn towards one side. As soon as it has turned so far that its plane of symmetry is in the direction of the rays, the symmetrical spots of its surface are struck by the light at the same angle and in this case the intensity of light and consequently the velocity of reaction of the photochemical processes on both sides of the animal become equal. There is no more reason for the animal to deviate from the motion in a

straight line and the positively heliotropic animal will move in a straight line to the source of light. (It was assumed that in these experiments the animal is under the influence of only one source of light and positively heliotropic.)

In a series of experiments I have shown that the heliotropic reactions of animals are identical with the heliotropic reactions of plants. It was known that sessile heliotropic plants bend their stems to the source of light until the axis of symmetry of their tip is in the direction of the rays of light. I found the same phenomenon in sessile animals, *e. g.*, certain hydroids and worms. Motile plant organs, *e. g.*, the swarm spores of plants, move to the source of light (or if they are negatively heliotropic away from it) and the same is observed in motile animals. In plants only the more refrangible rays from green to blue have these heliotropic effects, while the red and yellow rays are little or less effective; and the same is true for the heliotropic reactions of animals.

It has been shown by Blaauw for the heliotropic curvatures of plants that the product of the intensity of a source of light into the time required to induce a heliotropic curvature is a constant; and the same result was obtained simultaneously by another botanist, Fröschl. It is thus proved that the Bunsen-Roscoe law controls the heliotropic reactions of plants. The same fact had already been proved for the action of light on our retina.

The direct measurements in regard to the applicability of Bunsen's law to the phenomena of animal heliotropism have not yet been made. But a number of data point to the probability that the law holds good here also. The first of these facts is the identity of the light reactions of plants and animals. The second is at least a rough observation which harmonizes with the Bunsen-Roscoe law. As long as the intensity of light or the mass of photochemical substances at the surface of the animal is small, according to the law of Bunsen, it must take a comparatively long time until the animal is automatically oriented by the light, since according to this law the photochemical effect is equal to the product of the intensity of the light into the duration of illumination. If, however, the intensity of the light is strong or the active mass of the photochemical substance great, it will require only a very short time until the difference in the mass of photochemical reaction products on both sides of the animal reaches the value which is necessary for the automatic turning to (or from) the light. The behavior of the animals agrees with this assumption. If the light is sufficiently strong the animals go in an almost straight line to the source of light; if the intensity of light (or the mass of photosensitive substances on the surface of the animal) is small the animals go in irregular lines, but at last they also land at the source of light, since the directing

force is not entirely abolished. It will, however, be necessary to ascertain by direct measurements to what extent these phenomena in animals are the expression of Bunsen-Roscoe's law. But we may already safely state that the apparent will or instinct of these animals resolves itself into a modification of the action of the muscles through the influence of light; and for the metaphysical term "will" we may in these instances safely substitute the chemical term "photochemical action of light."

Our wishes and hopes, disappointments and sufferings have their source in instincts which are comparable to the light instinct of the heliotropic animals. The need of and the struggle for food, the sexual instinct with its poetry and its chain of consequences, the maternal instincts with the felicity and the suffering caused by them, the instinct of workmanship and some other instincts are the roots from which our inner life develops. For some of these instincts the chemical basis is at least sufficiently indicated to arouse the hope that their analysis, from the mechanistic point of view, is only a question of time.

9. Ethics

If our existence is based on the play of blind forces and only a matter of chance; if we ourselves are only chemical mechanisms—how can there be an ethics for us? The answer is, that our instincts are the root of our ethics and that the instincts are just as hereditary as is the form of our body. We eat, drink and reproduce not because mankind has reached an agreement that this is desirable, but because, machine-like, we are compelled to do so. We are active, because we are compelled to be so by processes in our central nervous system; and as long as human beings are not economic slaves the instinct of successful work or of workmanship determines the direction of their action. The mother loves and cares for her children not because metaphysicians had the idea that this was desirable, but because the instinct of taking care of the young is inherited just as distinctly as the morphological characters of the female body. We seek and enjoy the fellowship of human beings because hereditary conditions compel us to do so. We struggle for justice and truth since we are instinctively compelled to see our fellow beings happy. Economic, social and political conditions or ignorance and superstition may warp and inhibit the inherited instincts and thus create a civilization with a faulty or low development of ethics. Individual mutants may arise in which one or the other desirable instinct is lost, just as individual mutants without pigment may arise in animals; and the offspring of such mutants may, if numerous enough, lower the ethical status of a community. Not only is the mechanistic conception of life compatible with ethics; it seems the only conception of life which can lead to an understanding of the source of ethics.

SCIENCE AMONG THE CHINESE. II

By Dr. C. K. EDMUNDS
PRESIDENT OF CANTON CHRISTIAN COLLEGE

III. Alleged Anticipations of Modern Science

1. *Introductory.*—Some intimate students of Chinese literature and life, notably Dr. W. A. P. Martin, claim that in many cases Chinese philosophy has anticipated the doctrines of modern science. The same may be said of the ancient Greek thinkers, whose speculations have had a direct and large influence in the development of modern thought, such as the Chinese philosophers have not had. For it seems likely that the physical speculations of the Greeks, from which European science started, were a true native growth of the Greek mind and owed nothing to the lore of Egypt or of the east. (This is the opinion of Whewell as expressed in his "History of the Inductive Sciences.")

It is doubtless true that several of the guesses made by the ancients are in general accord with present theories as developed and supported by a wealth of observation, experimentation and inference. And it is true that the honors, if there be any, of having made such guesses, must be awarded in part to the Chinese as well as to the Greeks with this great difference, that in many cases the Greeks were true students of nature and checked their speculations by observation—a course which, though entertained by some Chinese philosophers, was not sufficiently appreciated by either them or their disciples to be put into practise.

The speculations to which we refer were developed during the glorious Sung dynasty, in the century A.D. 1020–1120, which stands preeminent among the forty centuries of Chinese recorded history as the age of philosophy. At the time when Europe was in darkness and the crusades were in full swing, the five famous philosophers—Chou, Chang, Cheng (two brothers) and Chu—were constructing the castle of faith and knowledge for their successors. It is from the writings of the last of these, the most famous of the five, that the foregoing quotations have been taken.

All five were Confucian scholars, but it seems likely that their mental activity was stimulated and directed by the speculations of Buddhist and Taoist writers. Their works derive importance from the fact that for 500 years, since the publication by imperial authority of the great "Encyclopædia of Philosophy," they have been the government standard, to which all aspirants for honors in the civil service examinations had to conform. They therefore represent the views of the educated men of

China to-day, not counting, of course, the few who thus far have been strongly influenced by western learning.

2. *The Ether.*—In the writings of these five worthies, Dr. Martin finds evidence (as exhibited in his "Lore of Cathay") that the doctrine of an all-pervading medium was familiar to the Chinese a thousand years ago, possibly even in the "Book of Changes," 1100 B.C., and that it was a full-fledged doctrine in several writers of the eleventh century A.D., who ascribed to this ether all the properties at present claimed for it except its electric and magnetic manifestations.

Here are some of the passages which bear on this point:

> Chang (in "Cheng Meng," or "Right Discipline for Youth"): The immensity of space, though called the great void, is not void. It is filled with a subtle substance. In fact there is no such thing as a vacuum. . . . Within the immensity of space matter is alternately concentrated and dissipated, much as ice is congealed or dissolved in water. . . . The great void is filled with a pure or perfect fluid. Since it is perfectly fluid, it offers no obstruction to movement. There being no obstruction (*i. e.*, nothing to bring about a change of state) a divine force converts the pure into the gross.

3. *Wave Theory of Light.*—In another place, according to Dr. Martin, we read: "The primal essence moved, and light was born;" and he says that the idea of vibrations was also grasped. In this he sees a forecast of the modern undulatory theory of light.

4. *Vortex Theory of Matter.*—In the work of Chou Dr. Martin thinks we may discern the forerunner of the modern vortex theory of the constitution of matter. Chou devised a diagram of cosmogony, consisting of a ring, or circle, of uniform whiteness, representing the primitive medium surrounded by a ring partly dark, which shows the original substances differentiated into the two forms or forces—*yin* and *yang*. Chu Hi, speaking of this diagram says: "It shows how the primitive forces grind back and forth like millstones, in opposite directions, and the resulting detritus from their friction is what we call matter."

But when we read in the context of the two writers concerning these two principles—*yin* and *yang*—and follow them in their absurd ramblings of fancy, it seems unwarrantable to suggest that the language of these selected sentences anticipates the idea of Lord Kelvin and leading present-day scientists.

5. *Conservation of Energy.*—Dr. Martin also claims that these Chinese thinkers apprehended with great clearness the doctrine of the Conservation of Energy, though they failed to fortify it by systematic induction. In the writings of one of the Cheng brothers there is this passage: "Body in motion is force. Its contact with another is followed by a reaction or effect. This effect, in turn, acts as a force producing another effect, and so on without end." "Here," he adds, "is a vast subject for the 'student of philosophy.'" But alas! Chinese "students

of philosophy" have not troubled themselves to verify this or any other of the guesses of their predecessors. Chu remarks: "Heaven and earth, with all they contain, are nothing but transformations of one primitive force." And in another place, not quoted by Dr. Martin:

> The primary matter in its evolutions hitherto, after one season of fullness has experienced one of decay; and after a period of decline it again flourishes, just as if things were going on in a circle. There never was a decay without a revival.

To be sure, here is the idea of transformation, but scarcely that of equivalence and conservation. Conservation implies quantitative relations, and such are certainly not expressed here or in the high-spun theories of the context, just as they are lacking in the common affairs of the people. The action and reaction of impact are expressed, but the statement contains no hint of the principle of conservation of momentum. And besides there is evident confusion, perhaps in the translation only, between "force" and "energy."

Can any proper conception of the ether and of the conservation of energy be ascribed to a man (and he, the best of their philosophers) who in the same connection in which occur the other passages already given, writes:

> Primary matter consists, in fact, of the four elements of metal, wood, water and fire, while the immaterial principle is no other than the four cardinal virtues of benevolence, righteousness, prosperity and wisdom. The great extreme, a principle centered in nothing, and having an infinite extent, is the immaterial principle of the two powers, the four forms and the eight changes of nature; we can not say that it does not exist, and yet no form or coporeity can be ascribed to it. From this point is produced the one male and the female principle of nature, which are called the dual powers; the four forms and eight changes also proceed from this, all according to a certain natural order, irrespective of human strength in its arrangement. But from the time of Confucius no one has been able to get hold of this idea.

And we might add, nor is it likely any one ever will.

6. *Evolution.*—Dr. Martin suggests that the fundamental idea of evolution was entertained by early Chinese sages. He quotes from Mencius:

> The study of nature has for its object to get at the causes of things. In causes the ground principle is *advantage.* [The italics are ours.] Though Heaven is high and sun and stars are far away, if we could find out the causes of their phenomena, we might sit still and calculate the solstice of a thousand years.

In this word, written 400 B.C., Dr. Martin seems to find an indication that Mencius knew how to set about the study of nature, and though not going so far as to say that in the word "advantage" we have an anticipation of Darwin's principle, he believes that this obscure hint, if followed up, might have led to Darwin's doctrine. But alas! the author of the quotation and all his followers for these two thousand

years "sat still," and so robbed themselves of the glory that might have been theirs!

7. *The Defect.*—It may be admitted that Chinese philosophers entertained some general ideas concerning an all-pervading medium, that they *assumed* an original unity of matter in all their cosmological speculations, that they had clear ideas on mechanical action and reaction, and very crude ones concerning the transformations of energy, which vaguely suggest those held to-day by the foremost investigators. But we see no just grounds for believing that they, or the Greeks, either, held any ideas comparable with the modern doctrines of vortex motion in the ether, of the conservation of energy, or of biological or cosmological evolution, for it does not seem to us that in the case of either the Greeks or the Chinese should their vague guesses be regarded as true anticipation of modern science. The *method* of modern science is its distinguishing characteristic, and this was almost completely lacking among the Chinese, and to a less extent among the Greeks also. There is a vast chasm between rampant imagination and scientific imagination, starting with observed facts and following paths that lead to results which can be directly or indirectly verified.

It is not enough to find in an ancient writer a few or even a considerable number of sentences seemingly anticipatory of modern thought. Nor must we neglect the hundreds of other ideas embodied in the context which distinctly are *not* in accord with modern science. We must observe the scope and design of the writer; inquire into his full aim and end in that book, or section, or paragraph, which will help to explain particular sentences. In particular propositions the sense of an author may sometimes be known by the inference which he draws from them himself; and all those meanings must be excluded from our interpretation of what was in his mind, which will not allow of that inference. Yet even in them we must take heed, lest we mistake an *allusion* for an *inference,* which is often introduced in almost the same manner. We must carefully guard against "reading into" an ancient writing the modern connotation of the term employed centuries ago, and that too as translated by means of a very dissimilar language in its present-day equivalents.

Too often these Chinese philosophers (as did the Greeks) assumed *innate tendency* as the basis of their crude and vague speculations. But innate tendencies are not looked upon with as much favor in the philosophy of to-day as in that of past ages, and suggestions so incapable of verification have little or no value as scientific hypotheses.

However interesting and worthy of notice the results of this guesswork may be as representing the philosophical creed of China, they are in the present connection simply a mass of cosmological conjectures into the details of which it would be unprofitable to follow.

IV. Causes of China's Backwardness

Some of the major causes of China's backwardness in science become apparent when we compare her philosophical method with that which has characterized modern western inquiry, and to set this comparison in stronger relief let us glance at some of the salient aspects of modern scientific knowledge, both as to method and as to content.

Some Salient Aspects of Modern Scientific Knowledge.—

A. *As to Method.*

1. *The inductive method of philosophical inquiry,* supplemented at times by the deductive. The study of many particular cases and the process of drawing a general conclusion based on observation, and the extension of the general principle thus deduced to individual cases not actually observed. Aristotle developed inductive logic, but William Gilbert of Colchester, the founder of the science of electricity and magnetism, first successfully applied the principles of inductive philosophy which later received such wide development under Francis Bacon. The ampliative inference of Gilbert and Bacon is to be distinguished as philosophical or real induction, in contradistinction to formal or logical induction. Philosophical induction has been the guiding star of all modern scientific effort and is responsible in no small measure for the remarkable progress thus far achieved. To-day the countersign of science is "method."

2. *The spirit of accuracy* in observation and the constant effort finally to express all observations in terms of the three fundamentals—length, mass and time. The coordinated and careful regulation of standards of measurement by all civilized governments under the guidance of leading physicists. Modern science is synonymous with "accuracy."

3. The development and wide application of the very powerful instrument of mathematical analysis, by which otherwise impassable fields of research are clearly traversed and made to yield their quota to our general theory of natural phenomena. The electro-magnetic theory of radiation in all its details is a most striking example.

B. *As to Content.*

1. Extension of the universe in space by the researches of the telescope, and of the microscope as well.

2. An all-pervading medium by which radiation, as manifested by either its chemical, optical, thermal or electric and magnetic effects, is propagated.

3. Extension of the universe in time, made necessary by observations in physics as to the rate of cooling of the earth, combined with observations as to the physical condition and evolution of the stars; in geology as to the time required for the formation of the strata of the

earth's crust; and in biology as to the evolutionary development of life.

4. The unity of the universe. (*a*) The doctrine of the conservation of energy as based upon quantitative investigation of energy transformations and the exact determination of equivalence factors. (*b*) The doctrine of evolution as based on a wealth of observation in astronomy, geology, biology, psychology, and the ethical and religious development of man. (*c*) The suggested unity of matter resulting from recent investigations of discharge of electricity through gases and the properties of radioactive substances.

On the other hand, let us glance at

Some of the Salient Features of the Chinese Conception of the Universe.—A. *As to Method.*

1. Absence of the inductive method; prevalence of *a priori* deduction from preconceived fantastic notions. Illustrations accepted as proof. Supposed analogy given highest weight.

2. Spirit of inaccuracy; in common affairs predominant; in system of weights and measures, where most needed for scientific progress, it almost defies description.

3. Lack of mathematical knowledge or method.

In the mere statement of these three characteristics we see at once three causes, or at least three related phases, of the general backwardness of the Chinese in science, which sum up to "no method." Let us examine each of these sub-heads a little more in detail.

1. *Absence of the Inductive Method.*—Chinese philosophers entered upon the task of physical speculation in a manner which showed the vigor and confidence of the questioning spirit, but no appreciation of the slow and patient process by which answers to nature's riddles are secured. They tried to discover the origin and principle of the universe rather by vague suggestions and casual analogies than by any course of reasoning that would bear examination. The first students wished, as do many to-day, to divine at a single glance or guess the whole import of nature's great book.

Western teachers of Chinese students are constantly impressed with their readiness to argue by illustration and to accept a single illustration as proof; not that they consider that a single exception to a rule invalidates its generality, but that from a single case a general law can be deduced. This is well shown by the following reply which was made by a college freshman in his geometry examination to the question: "What is a locus?" the class having spent a due proportion of the term on loci problems. He was by no means an unskillful logician from the Chinese point of view, though he may have lacked geometrical perception, when he answered "A locus is a straight line all the points of which are equally distant from the two sides." For he was simply

attempting to put in generalized form the first case of a locus which the class had studied, viz., that the perpendicular bisector of a straight line is the locus of all points (in the plane of the two lines) equally distant from the extremities of that line.

The method of the Chinese philosophers was *a priori,* and it seems that they adopted this course, not through ignorance of the experimental method, but from choice. The maxim of Confucius that "knowledge comes from the study of things" could not be more out of place than it is in his pages. The Chinese claim that their sage wrote a treatise on the experimental study of nature, but that it was lost; and thus they explain the backwardness of their country in experimental sciences.

Practical as the Chinese confessedly are, it is rather remarkable that in the study of nature their philosophers have made practically no use of the inductive method, though it appears that some of them at least had glimmers of its virtue as early as five hundred years before Gilbert and Bacon. In the writings of the brothers Cheng there is the following question and answer:

> One asked whether, to arrive at a knowledge of nature, it is necessary to investigate each particular object; or may not some one thing be seized upon from which the knowledge of many things may be derived.
>
> The master replied: "A comprehensive knowledge of nature is not so easily acquired. You must examine one thing to-day and another thing to-morrow, and when you have accumulated a store of facts, your knowledge will burst its shell and come forth into fuller light, connecting all the particulars by general laws!"

We say they had glimmers of the virtue of the inductive method, for it is hardly to be asserted that a philosopher really appreciated a method which neither he nor his disciples practised, but merely spoke of once. Contrast with the quotation just given this saying of Chang, the second of the five great thinkers of the Sung dynasty:

> To know nature, you must first know Heaven. If you have pushed your science so far as to know Heaven, then you are at the source of all things. Knowing their evolution you can tell what ought to be, and what ought not to be, without waiting for any one to inform you.

Between these two dicta we see the parting of the ways—one leading only to a maze of hazy unverified and unverifiable speculations, the other destined to bring any philosopher who followed it into the presence of valid generalizations based on observation; and we see the sages of China choosing the wrong pathway, vainly seeking a short cut to universal knowledge by following what they considered by the light of inner reasoning to be the order of nature, instead of laboriously studying one thing at a time in order to connect "all the particulars by general laws." Had her early thinkers taken the suggestion of the Chengs as their guiding star, China might to-day be the dean, instead of the most backward pupil in the school of science.

2. *Spirit of Inaccuracy.*—There is no more vexing factor in the life

of a foreigner than the utter lack of accuracy among the Chinese in most matters involving numerical relations. The ordinary troubles that one has with careless and even dishonest workmen and contractors are enhanced manyfold by reason of the discrepancies between the various measures used for different purposes though called by the same name. The method by which the units were adopted and fixed is lost in antiquity, and the variations in the measures now used destroy any claim that there ever was a true standard recognized in any such way as the standard yard and meter are recognized and employed by western peoples to-day. It is extremely hard to secure any adequate and consistent information concerning the weights and measures actually in use.

For instance, the *chih* or unit of length differs according to the province and the prefecture, the city and the ward, the craft and the usage. There are in the "Chinese Commercial Guide" over a hundred different values of the *chih* as actually in use. Some of these are doubtless derived from ancient official *chih,* but the majority seem rather to be the caprice of custom. The variations are by no means small, the extreme values differing by more than 6 inches in a unit of approximately 14 inches on the average. In Shanghai for instance, the carpenter's rule is 11.14 inches long, whereas the mason's rule is as short as 10.9 inches, so that in a building 100 ft. long, if this difference were not realized by the architect and he furnished the same specifications in Chinese measure to masons and carpenters, the frame of the house would overhang the stone foundations by two feet.

The distance between two points A and B, according to Chinese representation, depends not merely on the geometrical factor, but on others that determine the relative facility of travel between these points. It is further from A to B than from B to A, if B is upstream from A on a river, or at a greater elevation on a hill road. It is further between A and B at night or when raining than it is by day or when clear. While of course the practical philosophy of this way of regarding distance is evident, it still is true that such failure to separate these factors from the geometrical factor in the form of statement operates to retard appreciation of accurate statement and accurate thinking.

Paper may be sold by the hundred sheets and yet by a desire to keep the stated cost per hundred uniform in spite of variations in quality, the dealer will "call" a less number of sheets a hundred sheets, so that when you request your servant to buy a hundred sheets of a certain paper, he returns with eighty and insists that "in that kind of paper a hundred sheets are only eighty!"

Although a first impression of China and the Chinese may be that of deadening uniformity, it takes but a little closer observation to show that this is just the opposite of the truth. Along with the manifold divergencies in speech and customs, which play a paramount part in the

life of the people, and which by a common saying do not run uniform for ten *li* together, there is a like diversity in those standards of quantity upon the absolute invariability of which so much of the comfort of life and the entire advance of science in western lands depend. So far from suffering any inconvenience in the existence of a double standard of any kind, the oriental seems keenly to enjoy it, and two kinds of weights, or two kinds of measures seem to him natural and normal, and modern education is only just beginning to open his eyes to the inherent objections.

The whole Chinese system of thinking is based on such a different line of assumptions from those to which we are accustomed, that they can ill comprehend the mania which seems to possess the occidental to ascertain everything with unerring accuracy. Curiously enough, concomitant with the early development of their system of weights and measures—a decimal system for the most part—the Chinese have become fixed in the habit of reckoning by tens, and frequently refuse to make a statement of number nearer to the truth than a multiple of ten. An old man is "seventy or eighty years of age," when you know for a certainty that he was seventy only a year ago. A few people are "ten or twenty," a "few tens," or perhaps "ever so many tens." The same vagueness runs in all their statements, and for greater accuracy than this the Chinese do not care, except when you are paying them money.

The first generation of Chinese chemists will probably lose "a few tens" of its number as a result of the process of mixing a "few tens of grains" of something with "several tens of grains" of something else, the consequence being an unanticipated explosion.

The Chinese are as capable of learning minute accuracy in all things as any nation ever was—nay, more so, for they are endowed with infinite patience, but what we are here remarking is that as at present constituted they are entirely free from the quality of accuracy and that they do not know what it means.

Under such circumstances it is not surprising that so little real progress has been made in experimental science.

3. *Lack of Mathematical Knowledge.*—Although the study of arithmetic attracted attention among the Chinese from early times and numerous treatises are extant, and Hindu processes in algebra have long been known to them, yet these branches even down to the end of the Ming dynasty (A.D. 1664) made only slow progress. Trigonometry was introduced by the early Jesuit missionaries and since foreigners have begun to teach western science the development in these elementary branches of mathematics has been fairly rapid. But still the knowledge of mathematics is very small even among learned men; the cumbersome notation and the little aid such studies gave in the old-style examinations doubtless discouraged men from pursuing what they had

no taste for as a people. No such instrument as modern mathematical analysis, or even their stock of algebraic notions, has ever been used by Chinese philosophers or even conceived of as an instrument of research in their attempts to solve nature's riddles.

Besides the failure to adopt an inductive method of inquiry, the spirit of inaccuracy, and the lack of mathematical genius or training, there are other potent causes of China's scientific backwardness as compared with European nations, chief among which has been the character of the language and the method of instruction.

4. *The Language.*—Meager as our knowledge of the language is, we have yet had sufficient direct and indirect contact with the people to be convinced that the lack of inflection which would enable number, tense, gender and mood to be briefly expressed, operates to produce ambiguity and hence inaccuracy in the very places where definiteness may be most needed. To be precise requires a clumsy use of words and thus the character of the language has inhibited precise statements and so precluded accurate thinking, without which there can be no proper science. On the other hand, the European tongues existed in a highly inflected state as derived from the more ancient Greek and Latin, and hence by their very character aided in the conquest of nature by affording clearness and precision in the expression of thought, and thus fostered the validity of the conclusions reached. But the Chinese mind has been hampered by a language the most tedious and inflexible, and has been wearied with a literature abounding in unsatisfactory theorizings.

The non-alphabetical character of the language prevents the assimilation of new terms from European tongues and makes the introduction of modern scientific terminology and thought extremely difficult. To attempt to translate even where possible means cumbersomeness and circumlocution; to try to represent the new term phonetically by using Chinese characters that sound nearly the same—means that additional characters must be added to signify that phonetic value alone is intended, otherwise the apparent "meaning will be meaningless" and even if this sign is added, there is no hint of the real meaning of the term thus represented. In many cases the best that can be done is but a rough approximation, since there are many sounds in European tongues entirely unknown to the Chinese and difficult for them to acquire. About the only safe method in many cases is to introduce the foreign word as such in its own alphabetical form in the midst of the Chinese context—and thus necessitate the learning of it as a new "character" written on an entirely strange system.

5. *The System of Education.*[1]—(*a*) The spirit of inquiry has been

[1] See "The Content of Chinese Education," THE POPULAR SCIENCE MONTHLY, January, 1906, and "The Passing of China's Ancient System of Literary Examinations," THE POPULAR SCIENCE MONTHLY, February, 1906.

quenched by adherence to the notions of the ancients as containing all that could be learned. Yet even the knowledge of astronomy, for instance, which is contained in their books, has not been taught.

(*b*) They have set no value on abstract science, apart from some obvious and immediate end of utility. There has been no cultivation of knowledge for its own sake among the Chinese; their minds have not been broadened by the collection and investigation of facts; they have had few books, if any, on whose statements exact reliance could be placed.

(*c*) Political preferment was hitherto based on attainments in literature and politics; a knowledge of science was not used as a criterion and hence was not cultivated.

Thus throughout long ages the mind of China has been held in a false way, because no man of superior enlightenment arose to counteract the prevailing practise of putting thoughts in the place of things and facts, and it is likely that even had such a man arisen he would not have been able to counteract the attraction which drew all the vigorous and inquiring minds of the nation into the literary examinations. Hard labor then as now absorbed the energy and time of the masses while strife after official honors has consumed the talents of the learned.

6. *The Influence of Astrologers and Fortune-tellers, Geomancers, etc., and the Attitude of the Officials.*—The curious and intimate connection between geomancy, horoscopy and astrology, which the Chinese presuppose, has had a powerful influence, just as it had in former times in Europe, in maintaining their errors, because of its bearing on every man's luck.

Even when aided in no small measure by Europeans, especially by the Jesuit missionaries, the Chinese have seemed unable to advance in astronomy when left to themselves, and still cling to superstitions against every evidence. The speculations of their philosophers by their curious system of elementary correspondencies have led them away from carefully recording facts and processes, and they have gone on, as Williams says, "like a squirrel in a cage, making no progress toward real knowledge."

Even when more enlightened concepts of the realm of nature have been at hand and their acceptance even urged, Chinese officials have opposed their spread among the common people. There is not even yet an *adequate* government effort at popular education. The *chief* aim is still, as under the old examination system, the training of future officials and government servants. Europeans were employed for many years in compiling the calendar, but they were not allowed to interfere in the astrological part. The Chinese government apparently has deemed and still deems it necessary to uphold ancient superstitions, in order thereby to influence its own security and strengthen the reverence due it.

V. The Outlook

1. The language difficulty is being struggled with, style is being simplified, punctuation has been introduced. The language is growing and becoming clearer in the hands of modern trained Chinese. The development of the language so as to be able adequately to express the content of modern knowledge presents a most tremendous problem, which only native scholars highly trained in modern thought and equally familiar with their native tongue and its previous development can solve. It will take time, but this difficulty will ultimately be overcome. It is, however, an even greater problem than would have been presented had all the content of modern knowledge knocked at the door of eleventh-century English and demanded immediate expression. The unification of the language of the Empire as foreshadowed by the present determination to make Mandarin universally known will of course aid in this development. So long as this language difficulty remains so largely unsolved, it will be necessary to conduct the higher grades of instruction in the sciences with English as the medium—at least for those who are themselves to be leaders in this renaissance. To have a share in the preparation of men who will solve this problem is about as far as the foreigner can hope to go.

2. A more widespread contact with translations of western books is slowly but surely bringing the reading Chinese into a fuller appreciation of western or more scientific thinking. Their increasing familiarity with the inventions and methods of the west is undermining their superstition, as is also the spread of Christian theology. Recently we came across two very amusing indications of the difficulties involved in such an awakening among the common people—one in Shantung and one in Hunan, both with regard to the telegraph.

In Shantung an old farmer was seen contemplating the telegraph wire as it wended its crooked way across his fields. His neighbor remarked that the men who could devise and make use of such a line for the transmission of intelligence could do anything, but the old man replied that he did not think it was worth very much, because he had sat for some weeks watching the wire closely and he had not yet seen anything go by.

In Hunan, in traversing the main high road from Heng Chow to Yung Chow, we noticed a great number of worn-out straw sandals of carrying coolies, tied in pairs, hanging over the telegraph wire at many places along the line. At one place between poles, there were at least a dozen pairs, and on inquiring of the coolies what the meaning was, we learned that since the coolies were paid by the journey it was very advantageous for them to be swift of foot, and so when their sandals were worn out with much travel, if they succeeded in tossing a pair

so as to hang from the telegraph wire, they would have the good luck to be as swift of foot as was the electric message in its transmission.

3. Because of its contact with the west in trade, religion and education, and chiefly under the influence of mission schools the Chinese government has altered its educational policy, and the changes in the method of instruction and the system of education are for the most part tending to develop a spirit of inquiry and an appreciation of the inductive method, which will after a while begin to yield due fruit. When the influence of returned students who have been adequately trained in western countries and that of the graduates from first-class mission and government colleges becomes more potent, we can expect to see a much more rapid development of the educational system, but here again the magnitude of the undertaking and the difficulties as to efficient teaching force and adequate resources are such, that only natives can handle the ultimate solution. We teachers from abroad can hardly expect to do more than to give the impulse and to help in the preparation of the vanguard of such an advance.

4. When special and general education has proceeded far enough to provide the trained men needed to make the various adjustments involved in the tremendously complex and many-sided renaissance of this nation and to have provided the background of an enlightened people, there will of a surety be found among Chinese students many who will desire to follow the torch of learning and of truth for its own sake, some of whom, we believe, will attain a high degree of analytical power and experimental skill, for the Chinese after all are capable of exact and careful thought under right conditions, and moreover possess unusual patience and manual skill, so that in the long run we think they may be distinguished in regard to scientific attainments pretty much as the Germans have been for the last century. There are to-day in some of the universities of America and Europe Chinese students who in laboratory work in physics and other natural sciences are distinguishing themselves even in comparison with western students. The Chinese have a power of application and patience and a capacity for detail that is destined to bring success in scientific inquiry when once they get the background, adopt the method and make the start.

5. The irresistible progress destined to be made by western science in the Chinese empire will surely undermine Chinese faith in the "Book of Changes," which is at the base of Chinese philosophy. Whatever is permanently true will remain in imperishable blocks, but the structure as a whole will fall in ruins, with Chinese ideals pitilessly and irrevocably shattered. At this critical period of the disintegration of outworn forces, what new moral and spiritual ideas are to replace the old in order that the new state of these people may not be worse than the first?

Mere education in the science of the west, mere contact with western civilization, commerce, railways, telegraphs, mines, etc., can not be expected and are not calculated to regenerate China, because they have no direct moral or spiritual value, and the Chinese seem never to have been profoundly moved by other than moral and spiritual forces.

Education which deals only with coordinated physical or mental facts, conducted however thoroughly, does not prove adequate for the regulation of the conduct of mankind. It is so chiefly intellectual, that it leaves man's highest nature unsatisfied and almost untouched; therefore it is imperative in the present intellectual and material awakening that the more subtle forces which will profoundly affect the soul of the race should be fostered side by side with these others, and that full advantage be taken of the critical state presented by this transition, in order to gain for Christianity its rightful place among the educated men of the rising generation.

At the same time care must be taken to avoid repetition of the unwarranted conflict between science and religion. Our instruction must be such that these two departments are not regarded as antagonistic, but as supplementary, not only in affecting daily life and conduct, but supplementary also as revelations of the character and purposes of God. We must also avoid the tendency to impose a system which is the outgrowth of western civilization without due regard for the oriental character and mode of thinking.

The wide diffusion of Christianity in its best form will not suddenly introduce the millennium into China, for all intermediate stages must be passed through before the goal is reached, but it will for the first time in Chinese history, realize the motto of the ancient Tang repeated so impressively in these latter days by Chang Chi Tung: "Renovate, renovate the people." Thus alone can the empire be adapted to the altered conditions brought about by the impact of western thought. Christianity has been tried as yet upon a small scale only, but has already brought forth fruit after its kind. When it shall have been thoroughly tested and have had opportunity to develop its potentialities in a manner specially adapted to the situation, it will give to China intellectually, morally and spiritually the long sought for elixir of a new life.

NOTES ON NORWEGIAN INDUSTRY

By Professor JAS. LEWIS HOWE
WASHINGTON AND LEE UNIVERSITY

THE kingdom of Norway occupies about one third of the Scandinavian peninsula, and covers approximately 100,000 square miles of territory. From Vardö, its most northern point, to Lindesnäs on the extreme southern coast is 1,100 miles, 400 miles of this line being north of the Arctic circle. The northern portion of Norway is very narrow. A strip of Russian Finland extends westward to within sixty miles of the Atlantic coast, and to within twenty miles of tidewater on Bals-fjord. Mo, at the head of the Ranen-fjord near the Arctic circle, is but twenty miles from the Swedish frontier. At Trondhjem Norway has a width of eighty miles, but from here southward it rapidly widens, till north of Bergen it reaches its extreme breadth of about 250 miles.

The surface of Norway is for the most part barren highland, except in the south largely covered with great snow-fields till late summer, and much of it uninhabitable. The whole coast line is deeply indented by fjords, each with its many branches, all of deep water, and except in the extreme north rarely covered with ice. Into these fjords descend valleys, generally short and narrow, with precipitous sides. A few important valleys, generally in the south, are longer and broader, with gentler slopes. Each valley has its stream, fed from the upland snow, and often widening into a long, narrow lake. Along the coast are countless rocky islands, known as the Skjaergaard, which so fringe the shore that it is possible for a steamer to pass from Vardö to Kristiania with but few occasions to traverse the open sea. Norway thus resembles a chain of mountains with deeply dissected valleys, which has been sunk many hundred feet into the ocean. Such indeed may be considered the bare outline of a part of its geological history. In the north, Sweden is the more gradual eastern slope of this mountain chain.

The history of Norway has been largely determined by its physiography in the past, and we can not doubt that the same will be true in the future. The only habitable portions of the country being the narrow shores of the fjords and the restricted valleys, the pasture land being greatly limited and the arable land yet more so, the population was sparse and scattered, and few cities of any considerable size arose. To-day Norway has less than two and a half million inhabitants; of these about 230,000 are in Kristiania, 80,000 in Bergen, while Trond-

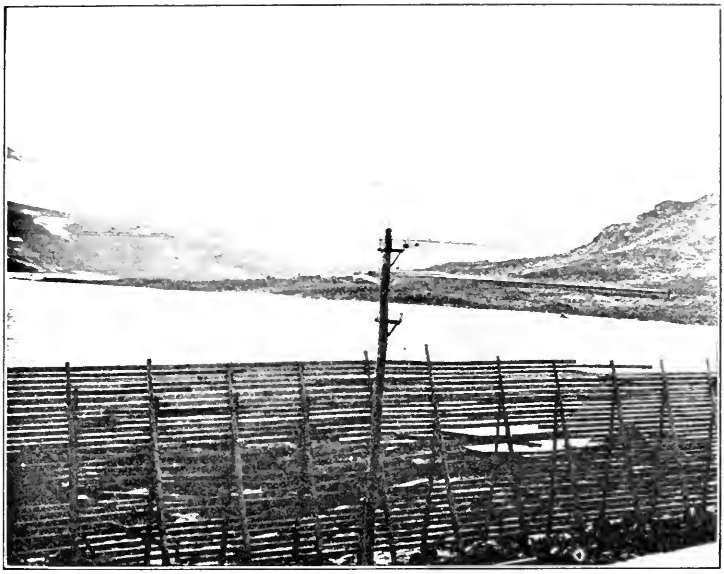


FIG. 1. NORWEGIAN UPLANDS IN SUMMER. Snow fences on the Bergen-Kristiania railroad.

hjem and Stavanger are the only other cities with more than 25,000 inhabitants, and only eight more have over 10,000.

Farming and grazing have always been the chief industries of Norway and at present more than half the population are so engaged. In the south, where the valleys are broader, general farming is practised, but in the north the life of the farmer is hard. Here the only crops are potatoes and barley, and these are cultivated in the bits of soil on the rocky mountain sides, even far north of the Arctic circle, indeed, it is said that the best potatoes are raised on Andö, one of the Vesteraalen Islands, at latitude 69°. Cattle are pastured in summer as far up the mountains as grass can be found, while every wisp of hay is gathered for winter use, not only on the lower levels, but among rocks and on slopes so steep that cattle could not find a foothold. Most of the calves are shipped, as comparatively few can be carried through the winter on the meager sustenance. Sheep and goats are raised but in small numbers.

Next to farming the chief industry of Norway is fishing, and in winter all the farmers living on the fjords become fishermen. The great center of the fishing industry is the Lofoten Islands, on the west coast, north of the Arctic circle. Here in winter and early spring assemble upwards of 40,000 fishermen from all of the fjords of western Norway, even from below Bergen. The fishing is chiefly in Vest-fjord, the broad, open body of water between the Lofotens and the mainland, for here the cod swarm in immense numbers. The fishermen scatter

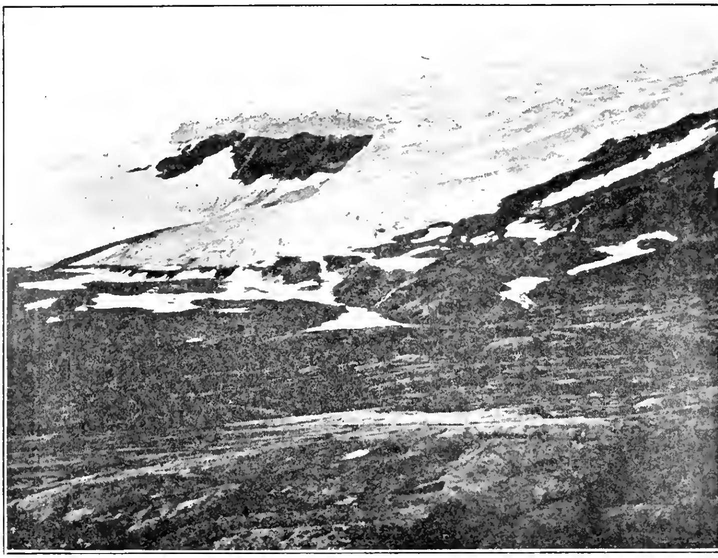


FIG. 2. NORWEGIAN UPLANDS IN SUMMER. Snow field near Djupvashütten. "In many places the snow has not disappeared by the end of summer, and thus furnishes a continual supply of water."

themselves in rude huts along the shore, and when the fish arrive they are notified by telephone. A season's catch is often valued at nearly $2,000,000. The fish are brought on shore and dried; the heads and backbones are ground for fertilizer, or boiled with hay for cattle food; the livers are tried for cod-liver oil. This fishing, like that of the Newfoundland Banks, is attended with great loss of life. Brought up in such a school, it is not surprising that so many Norwegians are sailors and that Norway ranks next to England and the United States in maritime commerce, nor that Norwegian masters command vessels in all parts of the world, from the whalers of Japan to the fruiters on our own east coast. In addition to the cod fisheries, the herring fisheries occupy many men, while a smaller number fish for salmon, salmon-trout, and market sea-fish, as well as lobsters.

The third great industry of Norway is that connected with timber. While the highlands are barren, the lower slopes, even far to the north, are densely wooded. The most important woods are pine and spruce, and in the more northern portions birch is abundant, indeed far beyond the line of conifers the white birch continues, until it becomes at last so stunted that it is hardly more than a bush, and we are above the tree-line. The fashion of building houses is evidence of the wealth of timber. In the north all houses are built of logs, hewn smooth on two sides and hollowed on the lower side to fit the unhewn, rounded top, thus avoiding a crack. At the corners and where the partitions meet the walls, the logs are carefully dovetailed together, so that the

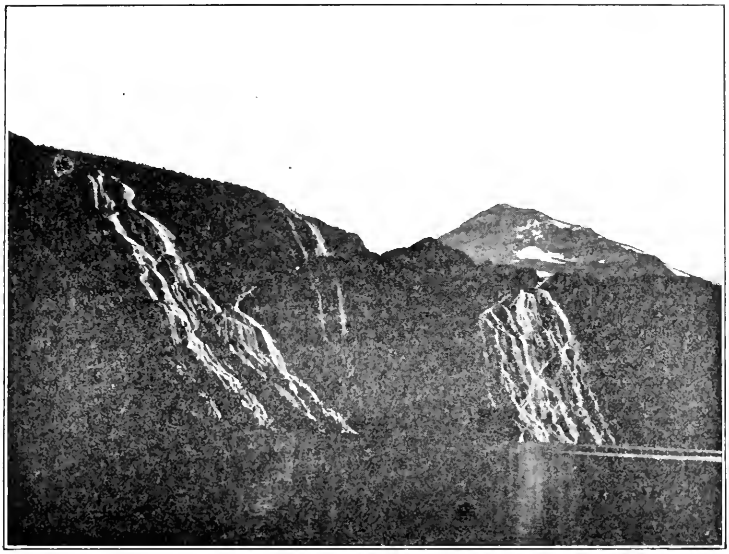


FIG. 3. WATERFALL ON HUNDVIK-FJORD. The steep walls of the fjords are often lined with such waterfalls.

houses present a very neat appearance. The roofs may be of slabs, shingles, slate, some of the latter being rather great flags of mica-schist, and in the poorer and older houses of turf. This turf often grows in a very flourishing manner, so that quite a crop of hay could be gathered from the roof. Farther south the houses are generally of the same type, but in the place of logs plank are used, from three to four inches in thickness. After my attention had been called to this point, I kept a lookout for ordinary boards, but the thinnest I saw were by actual measurement two and a half inches thick. From this almost wasteful use of lumber as it would seem to us, it follows that all Norwegian houses are very substantially built and one would imagine that they would be of rather slow-burning construction. The contrary seems to be the case, for almost every town of any size has been repeatedly devastated by fire, so that old houses are by no means common, indeed most Norwegian cities have a decidedly modern appearance. The city of Bergen has a number of broad avenues, purposely kept open to prevent the spread of fires. It should be added that stone and brick are rapidly replacing wood in the larger cities, much reducing the fire risk.

While large amounts of timber are used for building and still larger quantities are exported, by far the largest amount is used for wood-pulp. Here comes into use Norway's enormous water-power, for the so-called mechanical pulp is most largely manufactured. All over southern Norway are these pulp mills, where the wood is disintegrated by rough stones, much like an ordinary mill-stone. The pulp is

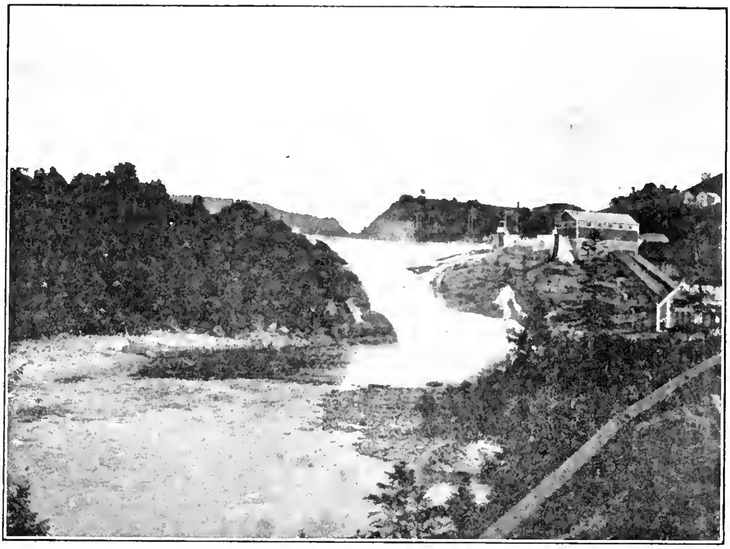


FIG. 4. FALLS AND POWER HOUSE OF TRONDHJEM ELECTRIC WORKS. Only a portion of the power of this stream is at present used.

thoroughly macerated by water and pressed into sheets, which are sold to the paper manufacturers of England, America and the continent. The logs are floated down to the mills in enormous quantities and the frequent lakes along the river courses serve as storehouses for the logs till used. One may often see acres of water thus covered with logs.

The one great drawback to manufacturing industry in Norway is the lack of all fuel except wood and peat. There is a little deposit of coal in one of the Vesteraalen Islands, but it is difficult to work and very little mined. On the coast it is of course possible to import coal, but this is hardly used outside of the larger cities. The ordinary fuel everywhere is wood, but this is naturally hardly applicable to industries. But if Norway is badly off for fuel, she is unique in her water-power. Doubtless the water-power of America surpasses that of Norway, but here it is scattered from Maine to Georgia, and from Idaho to Texas. In Norway it is everywhere, from Kristiania to North Cape. In winter the whole highland of Norway, and this includes the largest proportion of her area, is covered with deep snow. This melts very gradually and in many places has not disappeared by the end of summer. There is thus a continual supply of water, from elevations of six thousand feet down to nearly sea level. This water has a very short distance to go before reaching the sea, and few of the rivers are navigable for any considerable length. The many lakes found in their courses serve as inexhaustible storage reservoirs, while the short stretches of river connecting the lakes generally have a very steep fall. Norway thus abounds in waterfalls, the water often descending a thousand feet

FIG. 5. VIDE-DAL: A TYPICAL VALLEY. Fifty waterfalls were counted within two miles of the spot from which the picture was taken. The valley stream flows into a lake, one end of which is visible, and which is only 90 feet above tidewater.

or more in one or a few leaps. Her water power is thus Norway's greatest natural resource, compensating for her paucity of mineral wealth and lack of fuel. Upon this water-power is Norway's dependence for her industrial development.

In the early days on every farm might be seen little water mills for grinding grain and for mechanical purposes. At a comparatively recent date came the pulp mills and electric light and power plants. To the ordinary traveler it would seem that Scandinavia leads the world to-day in applied electricity. It is well known that Stockholm is better supplied with telephones than any other city of the world, having one instrument for every six of its inhabitants. One can send a telegram anywhere in these countries for thirteen cents. Even in the far north electric lights are generally used, and the fixtures and service leave nothing to be desired.. Kiruna, a mining town north of the Arctic circle, has an electric railroad.

The larger possibilities of electric industries are now being recognized in Norway, and capital is being rapidly supplied by the wealthier countries of Europe. Unless the restrictions placed upon industry by a government strongly tinctured by socialistic ideas shall prevent, Norway will in the near future become one of the greatest, if not the greatest, industrial center of Europe. In possibilities it yields only to America. At present there are about twelve electric industries already in operation in Norway and several more are nearly ready to begin work. These include such diversified manufactures as aluminum, sodium, zinc,

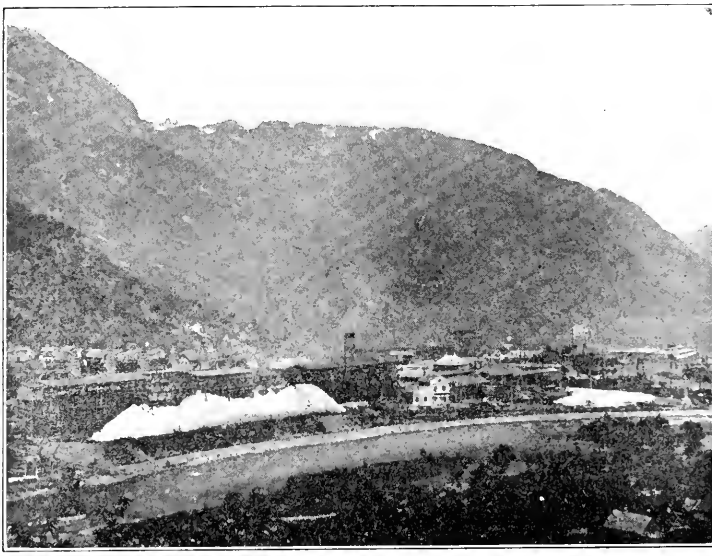


FIG. 6. ODDE: CARBID AND CYANAMID WORKS. A beautiful secluded nook at the head of Sor-fjord has been transformed into an industrial center, with an ever-present pall of smoke.

pig iron and steel, calcium carbid and cyanamid, nitrates and nitrites. Two lines of this development I have recently had the opportunity of studying rather carefully, and these will be described somewhat in detail.[1]

The first is the manufacture of calcium cyanamid. The history of this substance, which bids fair to become an important article of commerce, may be worth briefly recounting. In 1836 Sir Humphry Davy in preparing metallic potassium, obtained a substance containing calcium and carbon, which gave off a badly smelling gas when placed in water. A quarter of a century later Woehler obtained the same substance by fusing a calcium-zinc alloy with coal, and he recognized the gas which was evolved when this was put in water, as acetylene. In 1890 Winckler found that by reducing calcium carbonate by magnesium the same substance could be formed, and four years later Moissan prepared the substance, now recognized as calcium carbid, in quantity, by reducing limestone with coke in the electric furnace, thus founding the great carbid and acetylene industry of the present. Since the great development of the extraction of gold from poor ores by potassium cyanid, every effort has been made to prepare cyanid more economically, and in 1904 it was found that barium cyanid, the analog of calcium

[1] For much of the data regarding these plants I must express my indebtedness to the courtesy of Mr. G. W. Sinclair, of the Northwestern Cyanamide Company of Odda, and of Mr. A. Scott-Hansen, of the Norsk Hydro-Elektrisk Kvaelstofaktieselskab of Kristiania. For any comments I am alone responsible.

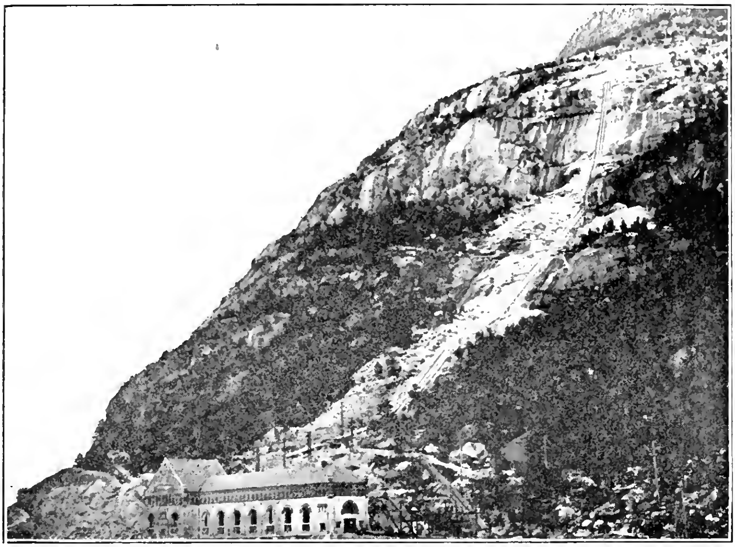


FIG. 7. TYSSA: THE POWER PLANT FOR THE ODDE CARBID AND CYANAMID WORKS. The water is brought down 1,450 feet in these two pipes, furnishing 22,000 horsepower.

carbid, when heated in an atmosphere of nitrogen, absorbed the latter forming barium cyanid. But barium cyanid is expensive, so that the same experiment was carried out on the cheaper calcium carbid, now an article of commerce, in hope that calcium cyanid would be formed. Nitrogen was indeed absorbed, but half the carbon of the carbid was lost in the process, giving not calcium cyanid, but calcium cyanamid, which contains for each atom of calcium two atoms of nitrogen but only one of carbon. A study of this new substance revealed the fact that when put in water it was decomposed and all its nitrogen given off as ammonia. Now with the inadequate supply of ammonia from gasworks and the decreasing supply of nitrate from Chili, the world has been staring a fertilizer famine in the face, and every effort has been made to devise some way of combining the nitrogen of the atmosphere for the use of growing crops. Here in this new discovery was a possibility of manufacturing ammonia, needing for raw materials only limestone, coal and air, all cheap, and an electric furnace. The last could be only economically used when the electricity was furnished by water.

A few years ago a calcium carbid plant was established at Odda at the head of the Sör-fjord, one of the most beautiful branches of the Hardanger-fjord. To turn the carbid into cyanamid merely requires heating in an atmosphere of nitrogen, and nitrogen composes four-fifths of the air. But the problem of separating the oxygen and nitrogen of the air is by no means easy of solution on a large scale. Suffice

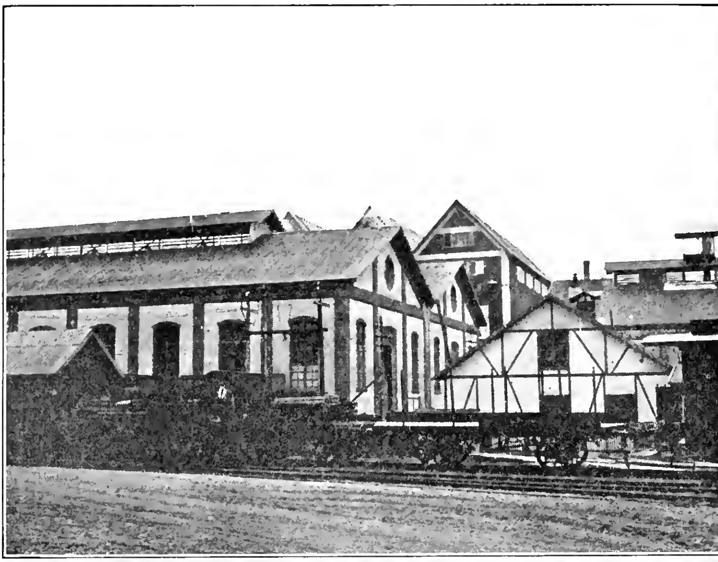


FIG. 8. NOTODDEN. PORTION OF THE SALTPETER WORKS NEAR NOTODDEN.

it to say that it is now accomplished industrially and it was my privilege to see the working of the whole process at Odda. The air is first liquified as in ordinary liquid-air machines, and then the constituent gases separated by rectification, using much the same process as that by which alcohol is separated from water. The difficulty of the process depends upon the low temperatures necessary. Oxygen boils at — 182° and nitrogen at — 194° Centrigrade. The air must of course be completely freed from moisture and also from carbon dioxid, for at the temperatures used both are solids and would clog the pipes. All the difficulties have been successfully overcome and from the stills the nitrogen is boiled off in an almost pure condition. Delicate tests in the laboratory show that on the average not over 0.2 per cent. of oxygen is present. The commercial weakness of the process is the fact that there is no use for the fairly pure oxygen which is left, which in many places would be very valuable and probably pay the whole cost of operating. The calcium carbid is ground and exposed for two days in an atmosphere of the pure nitrogen. While the absorption of nitrogen is an exothermic reaction, it must be started and supported in the initial stages by a supply of heat from some external source, and for this electric heating with carbon anodes is used. The resultant mass is a fairly pure cyanamid, with uniform nitrogen content of 20 per cent. From the cyanamid ammonia is easily obtained by the action of water, and this being absorbed by sulfuric acid gives the ammonium sulfate so extensively used as a fertilizer. At present the sulfuric acid for this absorption must be imported, but an electric zinc smelter is in process of

FIG. 9. HITTERDAL-KYRKE. This church, which is built of wood, has stood in this smiling valley for nearly 700 years. Note that the bell tower is across the road from the church.

construction which will furnish sulfuric acid as a by-product. In many cases it has proved simpler to use the cyanamid itself directly as a fertilizer, letting the moisture of the soil convert it into ammonia as needed. On many soils the nitrogen of the cyanamid is found to be equally efficient with that of ammonia or of nitrate, while on other soils it has less value. Its use has, however, become established and we may look for the installation of cyanamid plants in many places where water-power is cheap. A plant on the Canadian side at Niagara Falls is already in successful operation.

A word regarding the power of the Odda plant may not be amiss, as it illustrates the resources of Norway in this line. The power plant is at Tyssa, some four miles distant from the cyanamid works. The water is brought down to the dynamos in two pipes of rolled steel $1\frac{1}{2}$ inches thick and about two meters in diameter, with a fall of 1,450 feet, developing 22,000 horse-power for the cyanamid and carbid works. This is shortly to be increased by raising the level of the water supply, and it is said that there will be a development of 125,000 horse-power. The current is transmitted from the power house at 11,400 volts and is stepped down to 75 volts for the cyanamid manufacture and to 400 volts for the liquid air plant.

Another, and even more important effort to solve the problem of manufacturing nitrogen fertilizer from the atmosphere has been the attempt to convert the nitrogen of the air into saltpeter. It has long been known that when an electric discharge is passed through air, the

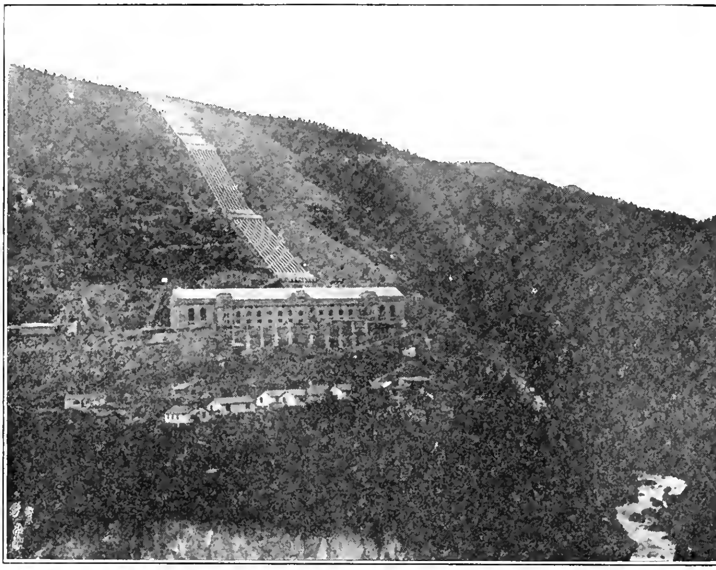


FIG. 10. RJUKAN-FOS UPPER POWER HOUSE. "The water is brought down in ten pipes, each unit to furnish 14,000 horse-power."

nitrogen and oxygen combine to form nitric oxid. This unites directly with more oxygen forming nitrogen dioxid, which when dissolved in water gives a mixture of nitric and nitrous acids. A very high temperature is necessary to cause the first union of nitrogen and oxygen, and at this temperature equilibrium is established when less than two per cent. of the nitrogen is oxidized. At a somewhat lower temperature the nitric oxid is decomposed into nitrogen and oxygen, so that it is no simple matter to cool this nitric oxid from the temperature at which it is formed, without having it completely decomposed in the process. This has, however, now been successfully accomplished at Notodden, where I was given an opportunity of inspecting the plant. A peculiar form of electric furnace is used, in which a flaming arc is driven back and forth along copper electrodes by electro-magnets. Through this arc air is blown, and in its passage a small proportion is converted into nitric oxid. It passes so quickly that very little of that which has been formed is decomposed, but on the contrary it is by the excess of air present converted into the dioxid.

The gases coming from the furnaces are cooled by passing through pipes in boilers, and thus incidentally furnish more steam than is needed for the whole plant, completely eliminating the item of coal, usually such an important part of the cost of manufacture in all industrial plants. The gases are then passed up large towers filled with broken quartz, down which water trickles. The oxid of nitrogen is absorbed, furnishing a dilute nitric acid. This is then pumped to large

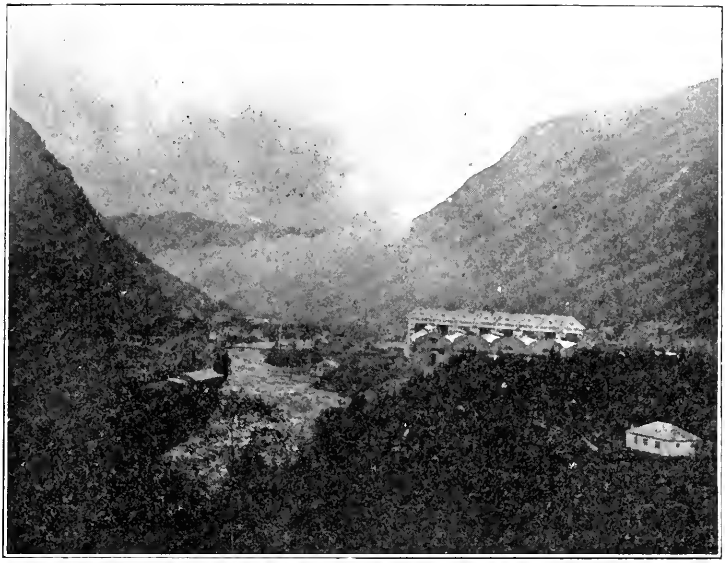


FIG. 11. RJUKAN-FOS SALTPETER WORKS. Looking down the valley. From this stream "within a few years 260,000 horse-power will be available, all to be used for nitrate manufacture."

tanks where it is neutralized with limestone, forming calcium nitrate or lime-saltpeter. The solution is evaporated and the resulting nitrate fused. It is either run in a melted condition into sheet-iron drums or into large tanks where it solidifies. The drums are sealed and are ready for shipment. The nitrate which has solidified in tanks is broken up, ground and shipped in air-tight barrels. It is guaranteed to contain 13 per cent. nitrogen, but generally runs somewhat higher. The market is of course unlimited, except as far as it is in competition with Chili saltpeter and with ammonium sulfate. It has been found possible to compete with Chili saltpeter even on the Pacific coast. The greatest difficulty which would seem to militate against the artificial product, is that it is very hygroscopic, or rather, deliquescent. This difficulty seems to be practically overcome by shipping the product in excellent wooden barrels manufactured by the works themselves. Experience and experiments have proved that the nitrate shipped in this manner keeps as long as it is practically found necessary. In many soils the presence of the lime rather than soda in the fertilizer is a distinct advantage.

Another product of the same factory is ammonium nitrate, for which there is a large market in the manufacture of explosives. For this the nitric acid is neutralized with ammonia (imported at present from England) and the solution evaporated to crystallization in vacuum pans, very similar to those used in sugar factories. The prod-

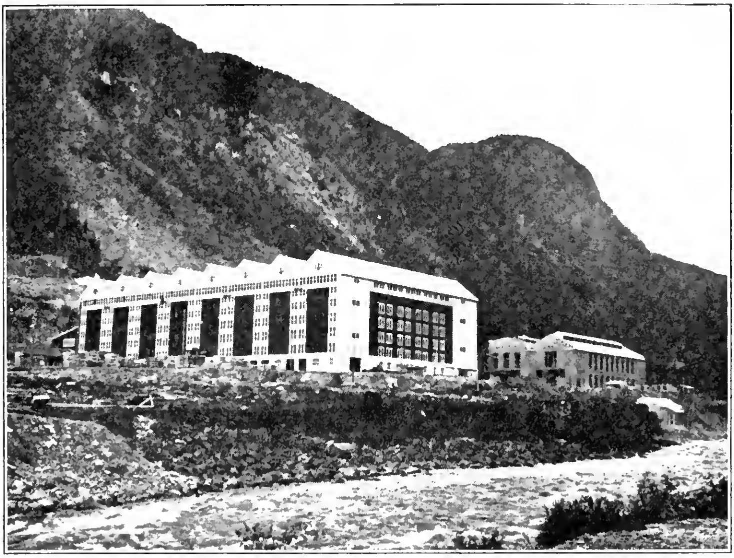


FIG. 12. RJUKAN-FOS SALTPETER WORKS. The water is carried from the upper power house to the lower through a tunnel just within the walls of the cliff. The current from both power houses will be brought to this building, in which will be utilized more electric power than any single plant in the world.

uct must be sold under a guarantee of 99.5 per cent. purity, but all the recent shipments I was told were 99.98 per cent. pure. Sodium nitrite is also manufactured, which is very extensively used in the color-works of Germany, and apparatus is being installed to immediately increase the amount produced.

At present in this plant 40,000 horse power are used, brought down from the Svaelgfos on the Tinelv, while farther down the same stream and in the outskirts of Notodden the Tinfos, with a fall of 65 feet, is utilized for pulp mills. Between these two falls on the Tinelv is another, the Lienfos, and here a dam is nearly completed which will furnish an additional 15,000 horse power to the Notodden works.

As soon as the success of the nitrate factory at Notodden was assured measures were taken to utilize the water of the Rjukanfos, higher up on the same watershed. This fall, though rather inaccessible, has long been considered one of the finest in Norway. The water plunges down more than 1,600 feet, almost 800 feet of this being in a single drop. Below the fall the stream is a mass of rapids for several miles before it reaches the beautiful Tinsjö, a "finger lake," some twenty miles long and perhaps two broad in its widest portion.

The engineering problem at the Rjukanfos was by no means simple, but is being solved by bringing the water down in two steps. From the top of the fall the water is carried in a tunnel and by open canal to a point above the upper works, which are near the foot of the fall, but

not on as low a level. To these works the water is brought down in ten pipes, each unit to furnish 14,000 horse power. After being utilized here the water is to be carried through a tunnel in the side of the mountain walls for about four miles, where it is again dropped, this time to the bottom of the valley. In the lower works 120,000 horse power will be obtained. Judging by the progress already made it would seem probable that within a few years the full 260,000 horse power will be available, all to be used for nitrate manufacture. The Tinelv drains an area of more than a thousand square miles of highland. One lake alone near its head waters has an area of fifteen square miles and an elevation of nearly 3,000 feet, while the water of Tinsjö which is below the Rjukanfos, drops 550 feet in reaching Notodden.

The development has been largely carried on by a Scandinavian-French company and by the Badische Anilin- und Soda-Fabrik, the great dyestuff manufacturers of Germany. These two companies have now combined their forces and each has a half interest in the Rjukan plant. A railroad has been built from Notodden to the foot of Tinsjö, and another from the head of the lake to the Rjukan works. A steam ferry-boat conveys freight trains the length of the lake and a larger one is now building by means of which all trains will go through without change from Notodden to Saaheim, where the lower Rjukan works are situated. It is said to be rather a cross for the owners of the railroad to run passenger trains, but this the government compels them to do. A busy town has sprung up at Saaheim and here, as at most industrial towns in Scandinavia, the workmen are well housed. Every house has a garden where not only vegetables, but also flowers are cultivated with great care. When I was there the poppies and dahlias were in magnificent bloom. In every window, and this is practically true all over Norway, were pots of flowers and Nottingham lace curtains. Notodden, on the other hand, resembled a western mining camp. It has the reputation of being the toughest place in Norway, and though prohibition is legally enforced, there is said to be a large amount of drunkenness. I must add, however, that during two months travel in Scandinavia I saw but three drunken men, one in Stockholm, one at Gellivare in northern Sweden, and the third in Notodden. It is safe to predict that this region of northern Telemarken, which includes the watershed of the Tinelv, will become one of the most important centers of electric industry in the world, though there may be a question as to whether Norway will be able to furnish sufficient labor for the increasing development. The Norwegians are by tradition and habit farmers and fishermen and it remains to be seen how effectively they can be transformed into industrial labor. Nitrate factories will naturally spring up elsewhere, since it is an industry, remarkable in that

the demand for the product is actually unlimited, while the raw materials cost almost nothing, limestone being the only expense, and no fuel is required. Any place where water-power is cheap and limestone can be obtained is suitable for a nitrate factory. With increasing supply the price of nitrate will of course drop, which will be a boon to the farmers. As there is unlimited water-power in Norway, and the industry is already established there, that land will have a great advantage in future competition.

As regards mineral resources, for a land of mountains Norway seems to be exceedingly poor. At Kongsberg are silver mines which have been worked for nearly three centuries, but the output is now comparatively small. They are more celebrated for the fact that the ore consists largely of native silver and some of the specimens, especially those taken out at earlier periods, are magnificent. The work in these mines seems to be kept up at present, not so much from productiveness or profit, as for the purpose of furnishing employment to the families of those who have been brought up in the mines.

In various parts of Norway copper is found and has been worked from time to time, but the deposits have thus far proved poor and limited in extent, and none of the mines have been commercial successes. The same may be said of the few deposits of coal and iron. It seems possible, however, that Norway may find an unlooked-for value in some of her deposits of minerals of rare elements, for which at any time there may be a great demand. Among her older rocks have already been discovered many minerals of great scientific interest, including Broeggerite, the most radio-active of known minerals. Nevertheless, it is to her unrivaled water-power that Norway must primarily look for her industrial development.

THE DUTIES TO THE PUBLIC OF RESEARCH INSTITUTIONS IN PURE SCIENCE

By Professor WM. E. RITTER

SCIENTIFIC DIRECTOR OF THE SAN DIEGO MARINE BIOLOGICAL STATION

THOSE most familiar with the Marine Biological Station of San Diego must have recognized that while up to the present moment it has devoted itself almost exclusively to research, an undoubted tendency has been manifested to depart from the strait and narrow way. Elementary instruction was given to young people several summers; an aquarium and museum open to the public free of charge were maintained a number of years; from time to time popular lectures and demonstrations have been given by the investigators connected with the laboratory; recently relations have been entered into with the California State Game and Fish Commission and with the United States Bureau of Soils for the investigation of industrial problems pertaining to the sea; and in various less obvious ways efforts have been made to be of service outside the realm of exclusive research.

It seems desirable to place on record more fully than has hitherto been done the ideas held by the scientific director touching the duties to the public of institutions for research in science generally and of this station particularly.[1]

As a point of departure for what is to be said we take the assertion that "Science for its own sake" as frequently understood is a false and unrealizable ideal. Science "for its own sake," art "for its own sake," wealth or anything else "for its own sake," if held without fundamental qualification, bears the germs of its own degradation if not of its death. Science can no more live "to itself alone" than can a human being. The fallacy prevalent here is in reasoning that because science and because art each has an exalted *intrinsic* nature and worth, it therefore has a nature and worth *quite apart from* its relation to other things and to men. Somehow it seems difficult to grasp the truth that the worth of science is in deepest essence *partly* intrinsic or resident, and *partly* extrinsic and relative. However, that its essential worth is thus two-fold becomes obvious upon reflection. On the one hand science has a nature of its very own, an absolute nature. It is not anything else whatever. It is not religion, it is not philosophy, it is not art of any kind, it is not mathematics, it is not commerce. At the same time,

[1] Indeed this little essay is in the first instance an administrative document addressed to the patrons and board of managers of the station.

equally true is it that science never has existed, nor can it be conceived as existing wholly apart from the world of *other* interests. For instance, science simply could not be without objects of nature to operate on, and appliances such as instruments and chemicals and literature to work with. And more interesting still from the standpoint of method, verification and confirmation (almost always by more than one worker) are entirely essential to science. Science is as certainly communal as it is individual.

The communal functions of science on the material side are sufficiently recognized in what is known as modern civilization. The incalculable worth of "applied science," commonly so-called, for human life under this type of culture is questioned to only a negligible extent. There is no need of either exposition or apologetic on behalf of this aspect of science.

Not so with science in its relation to the higher, the spiritual, life of men. Looked at from this standpoint it is truly surprising that the value attached to science should be so largely that of physical utility. To be sure, there is a rather general recognition that science, or certain aspects of it, are valuable for mental discipline, especially of the powers of observation. It is allowed, too, that science has an important function in delivering men from superstition. Beyond this little is claimed for science as a contributor to the higher needs and life of humanity. All along the line, educators, publicists, clergymen, politicians, journalists and, surprisingly, scientific men themselves, appear to take it for granted that the office of science is primarily to minister to man's bodily needs, and secondarily to sharpen his wits. If anything beyond this comes from it, so current opinion holds, this is quite incidental and secondary.

My belief is that science must justify its right to live and flourish, not alone by its ministrations to physical well-being, but also to the higher and highest reaches of man's nature. While I do not for a moment subscribe to the view held by a few, that science is everything, that by and by it will supplant religion, philosophy, ethics, art and the rest, I am fully persuaded that as civilization advances it must become ever more and more an underpinning and ally of all these.

The distinction between an institution of applied science and one of pure science might be stated thus: The former is one the primary aim of which is to use certain more or less well-established truths and principles of science to the answering of man's needs and desires in certain well-defined directions. For example, the Bureau of Soils of the United States Department of Agriculture is for the purpose of applying chemistry, physics and geology to the end of increasing the productivity of the land of the United States. The Liverpool School of Tropical Medicine is for the "perfection of physicians in tropical

hygiene" and for "investigations in tropical diseases." An institution of pure science, on the other hand, should be one the primary aim of which is to extend the bounds of man's knowledge of nature in a specified field, *and* to show something of the significance of the new knowledge for the higher life of mankind. To be more definite, an institution of research in biology or in astronomy could justify its existence, in a democratic country like ours, only by making considerable additions to knowledge *and then by showing in language comprehensible to the generally but non-technically educated members of the community, something of the meaning of this knowledge for human beings in both the physical and the spiritual aspects of their natures.*[2]

I now mention certain biological discoveries and generalizations which have, as I believe, very great importance to civilized men but which are by no means as widely known as they ought to be and might be, and which can become thus known *only through the efforts of professional biologists.*

The significance of *omne vivum ex vivo* (all life from preceding life) not only for philosophic biology, but for the attitude of thoughtful people generally toward the problems of practical living, should be more clearly and firmly grasped than it has been. That the dictum is solely an expression of the summed-up results of technical science and practical experience, that so far it has not encountered the crucial "one exception" and hence ranks with gravitation as one of the best established of nature's laws, and that its unescapable implication is that the succession of living beings in nature was without beginning, that is to say, has come from an infinite past, are matters readily susceptible of popular presentation and may be counted on to greatly interest many people were the subject to be presented by the biologist who himself had fully grasped the problems and clearly seen their significance for human life and conduct.

The generalization, based on an enormous range of observations, that *all organisms, including human beings, are subject in all aspects of their natures to the principles of evolution,* needs to be and may be far more widely and firmly implanted in popular intelligence than it is; and its bearings on general ideas of progress, social and other, and on popular estimates of perfection and imperfection, are very important.

[2] The soundness of this view is dependent upon the soundness of two assumptions which can not be argued here, but which may be briefly stated: (1) The person of average natural endowment and education in the United States is capable of understanding the most essential things in any scientific discovery that has ever been made or is likely to be made for many years to come. (2) It does "matter" enormously not only to the individuals, but to the nation as a whole, whether or not those who are capable of this much understanding have an opportunity to get it.

That biology has been forced, through its own advances, to recognize the *struggle-survival doctrine,* upon which she earlier staked so much as the cause of evolution, *is really of very subordinate importance in this way,* needs to be set forth to the general public far more emphatically and convincingly than it has been. Undoubtedly this strictly biological doctrine has been used to justify much cruel, destructive practise, particularly in the industrial world, and now that biology herself has found the doctrine to be so largely erroneous, it would seem the bounden duty of biology to rectify as far as may be the harm that has been done.

The conception of *"the reign of law" in the organic world* ought to be much more widely and concretely established than it is in the public mind. Under stress of the necessity of dethroning notions of supernaturalism from living nature, biologists have up to now been so occupied with explaining phenomena in terms of *natural causation* that the *orderliness* of organic phenomena has had to take a back seat both in research and in speculation.

The well-established truth that apparently all organic beings have in nearly, if not quite, all their parts and functions, *capacities far beyond those needed for ordinary life,* frequently far beyond what are ever used, except under very unusual circumstances, is of great significance for a general theory of life. But being a comparatively recent discovery, and standing in sharp contradiction to the widely prevalent views about the "economy of nature," and the utilitarianism of the Darwinian theory of natural selection, it has as yet found little place in either the learned or the popular theories of life. The general enlightenment needed on this matter might come partly from teachers, secular and religious, partly from psychologists, but most basally from biologists.

The conception of *the organism as a whole* that has been forcing itself into biology, particularly from the side of embryology, is destined to have a far-reaching, elevating influence on general beliefs, attitudes and practises. There is no likelihood that the idea will be brought into the full light of day unless biologists are the prime movers in bringing it there. Poets and poetical humanists in all ages have had much to say about "the whole man"; but the idea appears never to have germinated to the extent of greatly influencing the every-day lives of ordinary mortals. Biologists must be the original culturists here as they have been in so many other realms of things germinal.

The hypothesis that all phenomena of organic beings, including those pertaining to the very highest aspects of human nature, *are correlated with chemico-physical phenomena,* though not yet rigorously demonstrated in most of the subtler psychic and esthetic provinces, is securely established over so wide a range of life phenomena and has

thus far so well withstood rigorous efforts of disproof, that without doubt it has already greatly influenced general thought and attitude toward the deep problems of human life, and will more and more influence them. In a matter so vital, and one about which general intelligence is bound to be so widely astir for such information as can be had, it is of the greatest moment that information from the best sources should be readily available.

The laws of heredity, particularly those discovered by Mendel, have been tested to such an extent as to make them of positive moment to human life. The eugenics idea, started in England by Sir Francis Galton, aims at a practical application of the known principles of inheritance to the good of the human race. In view of the wide theoretic interest attached to these laws, and to the possible good that may come from their application to the propagation of man himself, the intelligent, thoughtful members of the community could undoubtedly be far better instructed than they are. Not only the possibilities, but the limitations of eugenics as a practical program ought to be and might be presented in simple readable language.

That imperium in imperio of human concerns, *the problem of the relation between the sexes,* is calling almost frantically to the biologist for help at certain points where, it is coming to be seen, he alone can help. A few investigators are doing splendid things in this domain, though what has been done is but as molecule to mountain relative to what remains undone.

Finally, without a doubt, *innumerable bald, unphilosophized facts of living nature that would entertain and instruct, and consequently keenly interest thousands upon thousands of generally intelligent persons, are buried in the technical language of biological narration and description beyond the possibility of extraction for such purposes except at the hands of biologists themselves.* Now many, perhaps not all, professional biologists are abundantly endowed by nature with the ability to do this extracting and preparing for general consumption. Acquiring the knack to do it is dependent first and foremost on being convinced that it ought to be done. The fact that many biologists develop splendidly the talent for graphic art in response to the need of illustrating the organisms and organs with which they deal, is proof positive that the art instinct is not wanting in them; and there is every reason to believe that this instinct would come out as literary skill here and there, as well as in the form of skill in delineation, were the need felt as keenly in the one case as in the other.

Assuming the contention to be sound that biological knowledge ought to be more widely disseminated than it is, and that so far as concerns the capabilities and desires of people such dissemination is possible, the familiar question arises, "What are you going to do about it?"

"The Schools!" Nine out of ten, I suppose, of those who would assent to my contention, would turn automatically in this direction.

To forestall doubt about my just appraisement of the school, the college, the university, in educating the young, I refer to an article ("Feeling in the Interpretation of Nature," THE POPULAR SCIENCE MONTHLY, August, 1911) in which I have taken the ground that these instruments ought to and could do vastly more than they do toward making the people appreciative of and intelligent toward nature. Here I would insist that no matter how efficiently and broadly the tasks of institutional instruction might be performed, they would still have to be extensively supplemented before the real saving power of knowledge could be realized. This supplementing would have to be done in two places particularly: In the home, for young children before school age is reached; and for grown-ups after the school period is passed.

Our eyes must be opened in some way to the fact that education, taken in the full sweep of its meaning, is too life-and-death a matter for us as a nation to be left to the formalities of the schoolroom, the university lecture hall and the laboratory, even though these be excellent beyond the possibility of improvement. This truth is being forced upon us at a few points. As one instance, it is becoming clear that wider instruction on sex matters is imperative, and that parents and the home primarily, and the school secondarily, must be looked to for the broader, better knowledge. Again the simply incalculable power of the press and the speaker's platform for educating and influencing the voting part of the population are recognized and resorted to upon occasion.

I may now state my views summarily: Biological science, as now developed, contains numerous facts and generalizations of very great moment to the higher intellectual and spiritual life of the people generally. The essence of these can be stated in language readily comprehensive to persons of average intelligence and education. Most, if not all, the facts and generalizations are of such nature as to make their strongest appeal to the majority of people only from their bearings on problems of personal experience, so that in the nature of the case they can be of living interest and significance to such persons only after the period of formal schooling is past and the business of actual living is on. Instruction concerning them must, consequently, be given by other means than the school. Some of the most important instrumentalities for such instruction are the botanical and zoological garden, the natural history museum, the aquarium, the library, the lecture platform and, in some ways most important of all, the public press.

And now for the culminating point: In the main the instruction given through all these instrumentalities must be by *professional biologists*. It will never be done well, that is, in a manner at the same

time vivacious, convincing, and dependable, by persons who have merely "read up" on biology with nothing but an elementary training to start from. Only persons constantly occupied with the first-hand gathering of data, with the making and testing of hypotheses, and with the submitting of results and conclusions to fellow workers for criticism and verification, can do the safest teaching in these ways.

Here comes not only the opportunity but the obligation of those whose vocation is in research institutions. The university teacher may generally be considered to have done his share when in addition to his research work he has instructed his regular classes. Those, on the other hand, whose lots are cast in institutions of research, being relieved of the round of duties incident to the university professorship, would seem to be marked as the ones to use such instruments of general education as are most suitable for reaching the great public outside the schools and colleges. The press, as already said, is probably the most available and powerful of all such instrumentalities.

I would not be understood to mean that every person regularly employed by institutions of research in non-industrial science should be held responsible for a certain amount of popular writing or lecturing or arranging of collections or the like. Such an idea put into practise would undoubtedly carry disaster in its train not alone to the institutions, but to the cause designed to be promoted. My view is that these institutions, *as institutions,* ought to hold themselves obliged, from time to time, to give out in a form readily accessible to and comprehensible by the rank and file, the results of their most significant achievements. Indeed, I am willing to go a step farther and say that such institutions might well be held to something of the sort by their boards of administration. I am persuaded that such a course would be, in the long run, not only not obstructive, but actually promotive, of the work of investigation itself.

It is true something in this way is being done by some, possibly all, of the research foundations of the country. But in very few, if any, so far as I can judge, is the doing accepted as a weighty obligation and as a set policy. So it happens that what is done is an exceedingly small fraction of what ought to be and might be done.

Under its present management the Marine Biological Station of San Diego holds duties in this direction to be as incumbent upon it as are those of making discoveries about the Pacific Ocean and the things that live in it.

SMALL COLLEGES

By Professor JOHN J. STEVENSON
NEW YORK UNIVERSITY

A COLLEGE-MATE recently indulged in wholesale denunciation of present conditions in American colleges; classes have grown so large that teaching is done mostly by instructors or assistant professors and students are drilled no longer by men of mature intellect; the intimacy between professors and students, which was the glory of the old college, has disappeared and with it has disappeared also the fatherly interest formerly shown by professors; the output of colleges is inferior in quality; there is no hope of improvement except in return to the small college of our youth.

As the one who drew this indictment had not been inside of college walls since graduation, his sorrow, like his knowledge, depended solely upon information and belief. He had forgotten that, more than half a century ago, when even Harvard and Yale were "small," some of our professors declaimed in similar fashion against those overgrown concerns and extolled the smaller college in which tutors were unknown and students met only professors. The dissertation has been delivered continuously during the intervening years, but its frequent appearance in print is of recent date and is due to the exigencies of so-called colleges which have sprung up like mushrooms all over the newer portions of our land.

The lack of frankness in use of the term "professor" is as painfully evident as it was fifty years ago. The colleges of that time, with few exceptions, had only professors, no matter how large the classes might be; but the term signified no more as to age, experience or qualifications than it does in the modern "small college." When the writer entered New York University in 1858, the college faculty consisted of nine professors, including John W. Draper, E. A. Johnson, Elias Loomis, Howard Crosby, S. F. B. Morse, Benj. N. Martin and others almost equally eminent—all except two less than fifty years old. Only three of the nine were more than twenty-seven years old when appointed to full professorships in the university and several of them received that appointment when only twenty-three. One of the others had been professor for eight years in another college and was only thirty-two when he came to New York. The same conditions prevailed elsewhere, all colleges having some very young men occupying important chairs,

They prevail to-day in the "small colleges," for students' year books, with half-tone portraits of the faculty, prove that youthful professors abound. But the conditions have changed in the larger colleges, for they have recognized not only the need of a higher standard, but also the necessity for subdivision of the classes to give opportunity for better teaching. In those one finds a head professor with others known as instructors or assistant professors. The age of these associates averages not far from thirty years and, for the most part, they are men of experience in their work. In the "small college" on the contrary, all alike are professors, be they elderly men or callow youth. It is difficult to understand how a young man as professor in a small college can be more efficient as teacher or guide than he would be if called instructor or assistant professor in a large college. Perhaps there may be something in the atmosphere which hastens maturity and renders experience unnecessary.

It is very true that in the larger colleges, as indeed in some of the "small colleges," the fatherly president has been replaced by a business president, whose duties as administrator prevent him from coming into close contact with the students and lessen his efficiency as head of the educational work—and one can not help regretting that this new officer has retained the old title, since the duties are so different. Yet the old officer remains, at least in the larger colleges, though under a different name. A university is not a mass of several thousand students; it is made up of small units or schools, each of which has its dean, who deals with the students directly as did the old-time president. In many institutions, the guardianship is still closer than formerly, each student being placed in direct relation to some member of the faculty, who is required to look after him. Arrangements for personal supervision and opportunities for association with teachers are many times better than they were of old. The supposition that in ante-bellum days there was any genuine intimacy between professors and students does not accord with the facts. The two bodies were in opposing camps and the time of faculty meetings was consumed largely in discussion of discipline cases—a condition wholly unknown now in the stronger colleges.

The "old inhabitant" remembers some severe storms of his youth and asserts that the climate has changed because old-fashioned winters are so rare. The "old boy" remembers some sympathetic professor, who loved boys because they were boys, and thinks of him as the type of his time. The one forgets the more numerous mild winters, the other forgets the more numerous indifferent professors; each remembers only that which made the deeper impression and each is surprised, almost indignant, when the record proves his memory defective. Faculties in the olden time were like faculties now; what change there is is

for the better. In the old faculty, there was always some one to whom troubled students could go, knowing that he would give the best he had of advice and sympathy; and that man is present in every faculty to-day. Reasoning *a priori,* the number of such men should be greater now. The college professor of a half century ago was apt to be a recluse, not a man of affairs. Too often, especially in the smaller colleges, he had become teacher late in life, having been more or less unsuccessful in another profession, which, naturally, he regarded as of higher grade than teaching. That type has not disappeared; but the college professor of the last three decades has had, for the most part, special preparation for his work; teaching is, for him, the noblest of professions; except in a few departments, he is a man of the world, not enclosed in a world of his own creation. With wider opportunities, he understands his fellows and can keep in touch with younger men. On the other hand, the student's life is broader, he is no longer regarded as something apart from his kind and he is better able to appreciate his opportunities—even though not always inclined to avail himself of them.

It is true that the output of our colleges in recent years does not give promise of equalling in average quality that of fifty years ago. The vast increase in number of students has not been in the best interests of true education; too many are seeking neither knowledge nor training; too many others are unfitted by native limitations or by early surroundings; they merely limp through the course and by dint of hard labor gain little more than the minimum demanded. It would be well for our colleges, well for the men themselves, if a great part of those now on college rolls should drop out and have no successors of their kind. The lowering of the standard in some quarters and the decreasing average of the output are due to their presence.

But those uttering the current laments respecting inferiority of output rarely consider matters of this sort; actual conditions have little of interest for them and they look far afield. The lack of frankness is nowhere more apparent than in the type of argument used to enforce the assertion that large colleges do not show results equalling those of the smaller ones. One would be justified in using a harsher term than "lack of frankness." Many advocates of present-day "small colleges," with 60 to 90 per cent. of their enrollment taking non-collegiate studies, are not content to say that their work is very good; they maintain that, if one may judge the tree by its fruit, their work is far better than that done by the larger colleges. In an address delivered several years ago at the inauguration of a college president, the speaker said that of the fifteen college graduates, chosen to the presidency of the United States, two thirds came from small colleges; that of seventeen graduates from fifteen colleges, who attained distinction in congress from 1870 to 1885,

only two were graduates of large colleges; while nearly ninety per cent. of the distinguished men in congress from 1870 to 1895 were furnished by the small colleges, which in addition have provided many of the most prominent men in the cabinet and other departments of the government. This is a thoroughly typical argument and is an admirable example of *non sequitur,* but it is effective, being easily comprehended by the most indolent intellect. One might take exception to it throughout on the ground that there are directions other than politics along which men achieve success, and that a training which induces men to seek political preferment as the *summum bonum* is hardly to be commended; but this would be merely a reflection on the speaker and not criticism of his argument.

The statement is partially true as to fact and wholly false as to implication. When the men referred to were graduated every American college was small; even Harvard, Yale, Princeton and Columbia were small, and two of them had fewer students than are claimed by some colleges whose presidents are bombarding the generously inclined with letters, circulars and speeches denouncing the evils of great universities; on the other hand, even the smallest colleges of the older days had more genuine college students than can be found in two thirds of the mendicant concerns to-day. The statement is imperfect in that it is a suppression of the truth. Geographical considerations enter into the choice of presidents, congressmen and cabinet officers. Political parties do not go to the eastern border alone for candidates; not every office seeker in the central and western part of this country could attend the older colleges of the east. If among the candidates there were men with college degrees, they were necessarily men from the local schools.

But exception must be taken to the lists as usually given. Selecting men from colleges which since the war have become great, and comparing them with those from colleges which, for various reasons, have remained small may be ingenious, but no stretching of courtesy could make it ingenuous. Yet even with that, the larger colleges do not suffer. No one would consider accidental or compromise presidents, such as Polk, Pierce, Hayes, Buchanan and some others as in any sense comparable with the Adamses, Madison, Roosevelt or Taft.[1] More, the mode of comparison makes use of ancient history as though it were that of recent times. No conclusions are to be drawn from lists of men prior to 1895, for present conditions did not exist in their college days.

[1] Jefferson is not included, because, through bad location and the mishaps of the Civil War, his college remained small; he is often listed as proving the superiority of the small college, though at the time of his graduation William and Mary rivalled Harvard in public esteem.

In any event the mode of comparison is absurd. It can be used, it has been used to prove that college training is without advantage, for down to twenty years ago, the vast majority of prominent men had never attended college. The remarkable increase in college students has come within three decades: recent graduates still labor under the burden of contemporary criticism.

But a more serious matter remains. The use of the term "small college" is a mere play on words for the clamorous small colleges of to-day are in no sense the successors of the small colleges of long ago. Dartmouth, Amherst and Williams in New England, Union in New York and Jefferson in Pennsylvania are often held before the admiring listener as prototypes of the small college; yet each of them had graduated classes of 40, 60 or even more in years prior to the civil war. There were other, smaller colleges with 100 or less students which equalled the larger in grade; but the 100 or less students included only those studying the regular course, the list did not include children in elementary work. All those older colleges had a narrow curriculum, but it was definite; the faculties were small, but they were competent to do the required work. It is certain that the modest ante-bellum colleges in some cases showed great results—but only where proper material was provided. There were many little colleges whose faculties were as earnest and as faithful as the best, yet one finds among their graduates very few who became even modestly prominent in any calling or profession; the reason being that they had not a strong type of people as constituency. Not the size of the college, but the type of students was responsible for the result. Colleges situated amid sturdy communities have long lists of men eminent in every kind of work. The men were there before they went to college; the elements of success were innate; no training, no education can impart them. Dartmouth and Jefferson, large for those days, Center of Kentucky and Bowdoin of Maine, small colleges of those days, are typical. The reader will think at once of others, similar in type.

As has been said, a very great proportion of the present-day schools, glorying in the title of small colleges, have little resemblance to those of earlier days. True, they are burdened with unremittent financial stringency and the requirements are modest—but with these the likeness ends. The curriculum in the old colleges was narrow, but it was compulsory, and its definite aim was to prepare men for undertaking professional study. Too many of the newer colleges, while pretending to be legitimate successors of the older, offer a curriculum of amazing range, music, art, pedagogy, semi-professional studies and elective courses in college work. In looking over the announcements, one is apt at times to imagine that at last he has found the ideal institution

in which instruction can be obtained in almost every subject under the sun. When he looks at the student-roll, he is surprised that so few have been attracted by a feast which promises to be so refreshing. But when he examines the list of teachers, surprise vanishes. If those teachers are competent, mentally and physically, to perform the task assigned in the announcements, it is no longer necessary to hark back three centuries to find a world's prodigy in the admirable Crichton; our land is full of them. These academy-colleges have little in common with the modest colleges of sixty years ago; those were substantial, these are superficial; they can not do well what they promise, for they are without equipment, and much of what they offer has no place in college work.

The conditions are made clear in an official report presented by the supervising board of a leading denomination, which, with rare frankness, gives complete statistics of all its beneficiaries. This board, during several years, has been trying to raise the standard and to eliminate from its list all institutions whose claims to the title of college are based chiefly upon the charter. In some cases it has combined schools, reducing one or more to the academy grade and reserving college rights to but one of the group; in several cases it has refused aid except on condition that no degrees be granted and that the so-called college accept rank as an academy of sophomore or, where the equipment is good, of junior grade. But its pathway is strewn with thorns, for local pride, local denominational jealousies and man's desire for post-mortem glory have enabled some merely town schools to accumulate a great amount of property; the danger of legal complications prevents application of the proper remedy. Yet in spite of the board's efforts, almost one half of the colleges report less than fifty students taking "college courses," and the number taking such courses is from .008 to 40 per cent. of the total enrollment, the higher percentage being in the smaller schools. The owners of these schools point with pride to the fact that a great proportion of their graduates enter the ministry, which they think justifies their existence. It might be well to ascertain what they have done in the way of educating those men, beyond granting them diplomas. They usually proclaim loudly their firm adherence to the old-fashioned classical course—perhaps because the equipment is inexpensive—but the writer has read in a letter from the president of a great theological seminary, that the most serious burden to his faculty is the imperfect knowledge of Greek shown by the students—all of whom are college graduates. The presidents of some of these schools plead that a college with 200 or more students has proved its right to generous support; but they include in that number all preparatory students and those receiving music and drawing lessons as well as

children taking elementary studies. One can only wish Godspeed to any denominational board which endeavors to bring order out of such chaos.

The vicious conditions found in large universities exist in smaller colleges, where they are fraught with more of danger. Students' year books tell of football, baseball and other teams; the athletic field is all-important and the official announcements in some cases dwell on its extent and attractiveness with greater gusto than is expended on description of the curriculum—possibly because a man prefers to write the truth. In the small college as in the large physical culture is acquired by proxies—the teams, which are supported under social compulsion. In some, the wandering glee club is present and the inter-collegiate contest is familiar throughout. Most of these "colleges" are coeducational and the number of male students is small, so that the proportion affected injuriously by these advertising schemes is much greater than in the larger colleges. The claim, so often asserted in circulars and advertisements, that the country village is free from vice, whereas that stalks openly in a city, is not in accord with fact. The writer has been professor in both country and city and he knows that there is little difference in this respect; but what difference there may be is in favor of the city as the safer place for the average boy.

Yet the longing, so often expressed by old graduates whose sons are now in college, has much to justify it. There is a wide-spread conviction that the educational condition is lamentably bad. But the longing is not for return to the old college with its lack of equipment; it is for return to the definiteness of the old curriculum, for escape from the aimlessness of the present curriculum. The university has been engrafted upon the college, while the ambition of high-school officials has diverted those schools from their true aim so that they encroach upon the college. Between university and high school, the college or mental gymnasium is threatened with extinction.

The university method of broad selection or of specialization in narrow groups is not for boys without stern intellectual drill. As matters now stand, a lad, crammed to pass an entrance examination, but untrained in the art of thinking, is thrown into university conditions to choose his courses, though neither he nor, in most cases, his parents are competent to determine the selection. The university and the college should be differentiated and the old-time method should be revived. In that, training was the main purpose; it was not, as now, secondary to athletics or tertiary to increased numbers. This is not to say that the narrow curriculum should be revived. That was designed to meet the supposed needs of men looking forward to the

Christian ministry; it neglected an important side of the intellect, gave an imperfect culture and left the man with a false conception of his acquirements. The curriculum should be designed to accord with modern conditions, should deal more with what is around us and less with mere abstractions; more with matters exercising the power of reason and less with such petty niceties as linguistic problems. Such a course of study, recognizing the many-sidedness of the intellect and compulsory throughout, would be the ideal gymnasium in which to prepare a young man for undertaking professional studies or for assuming the responsibilities of business life.

This work can be done only in a large college equipped with real libraries and laboratories, where the man may study under real professors, not jaded by teaching elementary subjects to academy pupils; where there is no mingling of college students and preparatory pupils in the classroom or on the campus; where the child who can do little more than read will not be "in college." A restricted, stringent curriculum would repel the slothful and indifferent, and fewer teachers would be required. Living salaries could be paid even with present endowments and the proverbial apprenticeship to poverty would not be necessary to enable a professor to live on his pay. The universities should confine themselves to graduate work. They should admit to their professional schools only those who have a college degree, earned not in correspondence schools or in college annexes, but by actual attendance at an institution maintaining the required standard. The country is not suffering from a famine of lawyers, physicians or even of clergymen, and the time is ripe for raising the requirements in all professional schools.

It is true that this procedure would have serious consequences. A not inconsiderable number of "small colleges" would find their degrees without value: they would lose their hold on the innocent people who have wasted money on them and their requiem would not be delayed. There would not be enough graduates to fill the numerous professional schools and only the best equipped would survive. But there is reason to believe that in each case the public grief would be neither widespread nor inconsolable.

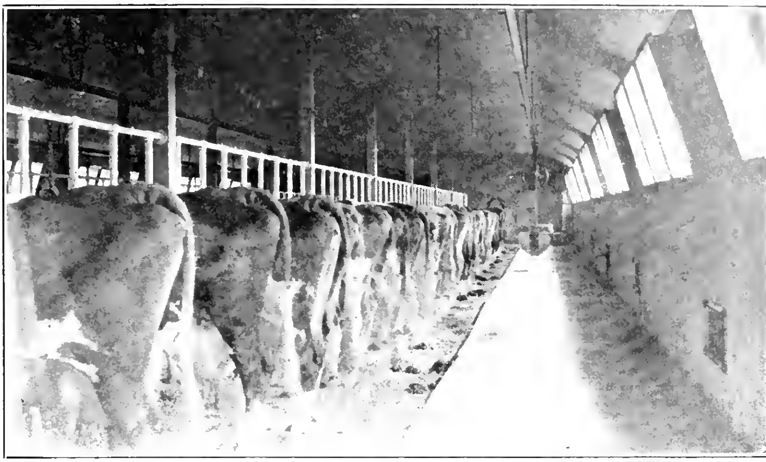
THE PROBLEM OF CITY MILK SUPPLIES

By P. G. HEINEMANN, Ph.D.
THE UNIVERSITY OF CHICAGO

MILK and various dairy products have been used by the human race for ages. There is evidence to show that at least 50,000 years have elapsed, probably a much longer period, since man began to use cow's milk for his own purposes. Savages who have no historical records consume milk—sweet, sour and fermented—to a large extent and have made use of the preservative properties of sour milk for keeping meat from putrefaction. The scriptures mention the fact that milk, sour milk and butter were common articles of food among the Hebrews. The ancient Greeks and Romans used milk and cheese and among the ancestors of the Anglo-Saxon, German and Scandinavian tribes the dairy herd was an important asset.

Perhaps the antiquity of the dairy industry is responsible for the extreme conservatism practised. The methods of taking and handling the raw material—milk—remain primitive to this day. Although forming one of the most important and universal articles of food, of special value in the feeding of infants, little progress has been made in that part of the production of dairy products, which is the controlling one from the public health standpoint, namely, the process of gathering the milk and its treatment before it reaches the consumer, the dairy or the creamery.

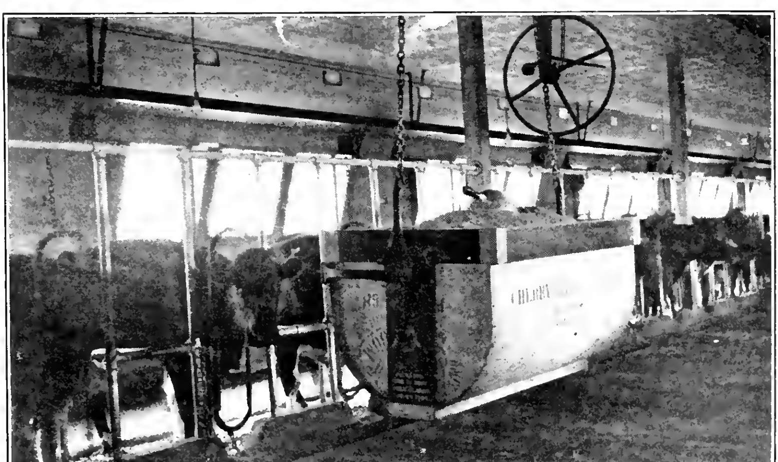
The sciences of hygiene and bacteriology are of relatively recent origin and with them came the knowledge that wholesomeness of food as well as sanitary environment is for the most part a matter of cleanliness. Now, few things are farther from cleanliness than the ordinary manner of milk production. Even if we admit that "pigs is pigs," milk is not always the same, and milks from different sources may vary enormously. Who has not seen a barn, where cows, horses and pigs are stalled under the same roof? Filth, cobwebs, dust, manure are allowed to accumulate and at long intervals are shoveled to a place, which is not far from the barn, where they dry out and are blown in the form of dust into the barns. Ventilation in the barn is absent, screens to keep out the disease-carrying flies are rare, light is admitted by small windows and the cows are permitted to rest in their own filth, which covers the hide, dries and is brushed or shaken into the milk when this is drawn from the udder. The modern cow is covered with filth and the owners ridicule the suggestion that cows deserve more care than



Photograph 1

horses. The cow, which furnishes the most valuable food for the human race, is thus neglected, while the horse, which is used for work only, is kept in good condition. Even from financial considerations should cows receive great care.

And what is the condition of cleanliness of those who attend to the milking? Do they change their clothes for clean ones before milking? Do they wash their hands? Far from it. Any suit of clothes, covered in some cases by dirty overalls, is good enough for tending the cow. The hands are not washed and just before milking are wetted with milk, water or even with saliva. Thus the dirt is washed from the udder into the milk. The virus of contagious diseases is sometimes carried from



Photograph 2

PHOTOGRAPH 3

the milker to the milk and epidemics of serious nature are thus started. Not least in importance is the universal presence of flies in cow barns. Flies may act as carriers of disease germs and should be kept out of barns as much as possible. It is true, that when entering barns the cows are bound to carry some flies with them, but by careful screening and by cleanliness of the floors and walls the number can be reduced to a minimum.

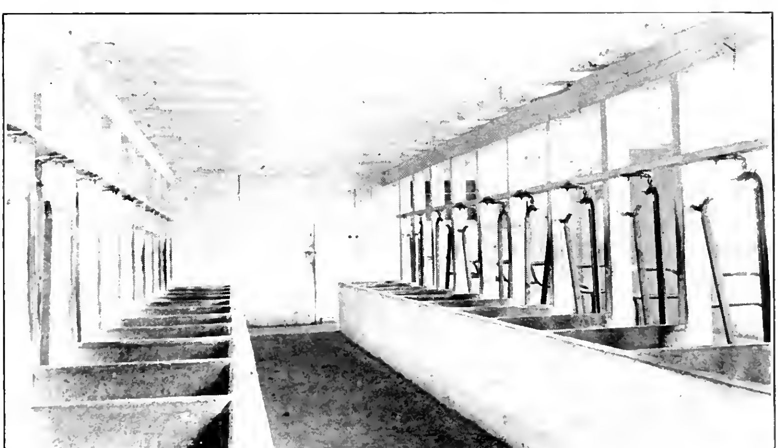
Such is the food we consume every day, such is the food which we depend upon for bringing up our babies, if the mother is unable or unwilling to nurse her offspring. A careful mother will clean the bottle, which serves to carry the food for the baby. The farmer thinks his duty is done if he washes the milk pails and other utensils with ordinary cold water. The water is sometimes obtained from wells situated in dangerous proximity to the outhouse, or from streams which carry sewage from neighboring farms or settlements. After washing the receiving pails in a careless manner there is enough milk left in them to cause disagreeable odors, but, nevertheless, the fresh milk is drawn into these vessels.

Milk is destined by nature to feed the young of mammals. They suck it directly from the teats and the danger of dirt being taken with the milk is comparatively small. But we take the milk from the cow under artificial conditions and have to use precautions and safeguards to prevent dirt from being mixed with the milk. The "cowey taste" sometimes innocently supposed to be characteristic of fresh milk, is due to nothing but cow manure, which has been suspended and become part of the milk during the process of milking. It has been estimated that the population of large cities consume hundreds of pounds of cow manure daily with milk.

What does the farmer do with the milk after his cans have been filled? In many cases the cans have no covers and instances are known where open cans are kept over night in filthy barns. Odors are taken up readily by milk and chickens and other fowl find comfortable places for roosting on the cans. The amount of milk sold that contains little or no filth is small. Such milk is necessarily higher priced than ordinary milk, as many precautions have to be observed to produce it. It is higher priced, however, only in a sense. By paying more for each quart we get a pure article with full food value, and have a reasonable assurance that no diseases are communicated that way. Thus there is really a saving, as diseases are always expensive.

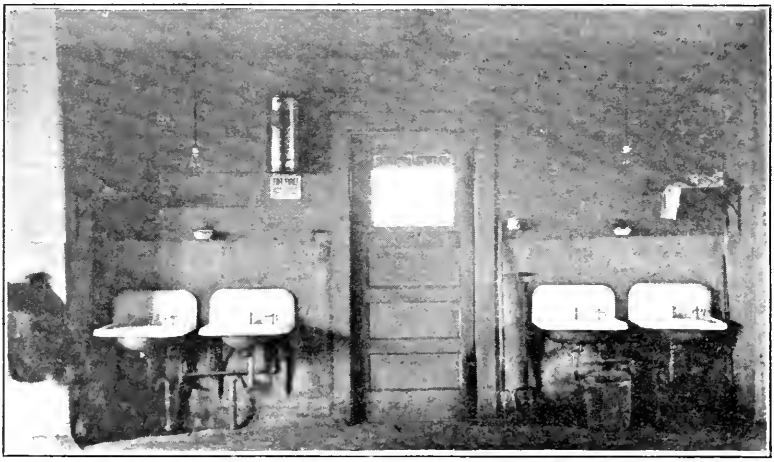
How is it feasible to procure milk which is satisfactory from the standpoint of the sanitarian? The principal thing is that the consumer demand a good product and he must know what constitutes good milk. It is relatively easy to discover rotten eggs, decayed meat and vegetables, because these are betrayed by the odor. Milk, however, does not putrefy in the way eggs and meat do, and even the taste is apt to be misleading. Chemical and chiefly bacteriological tests are the only safe guides to the detection of poor milk. For it must be remembered that fresh clean milk, which contains few bacteria and is safeguarded against their entrance, will not spoil for many weeks. It decomposed more or less rapidly in proportion to the numbers of bacteria present, and bacteria enter milk chiefly with dust, dirt and through the agency of flies. The problem then is to prevent bacteria as much as possible from gaining access to milk and this object can be attained only by scrupulous cleanliness.

The enormous mortality of infants is thought to be largely due to poor milk. In some localities a successful battle has been fought and is



PHOTOGRAPH 4

being fought against poor milk, in many instances with gratifying results. A reduction of infant mortality is usually noted when the public milk supply is improved. Laudable efforts are being made by health authorities in various cities in this country by introducing ordinances, forbidding the selling of milk derived from tuberculous cows, unless the milk is pasteurized. It will, however, require the intelligent and active support of consumers to make these efforts successful.

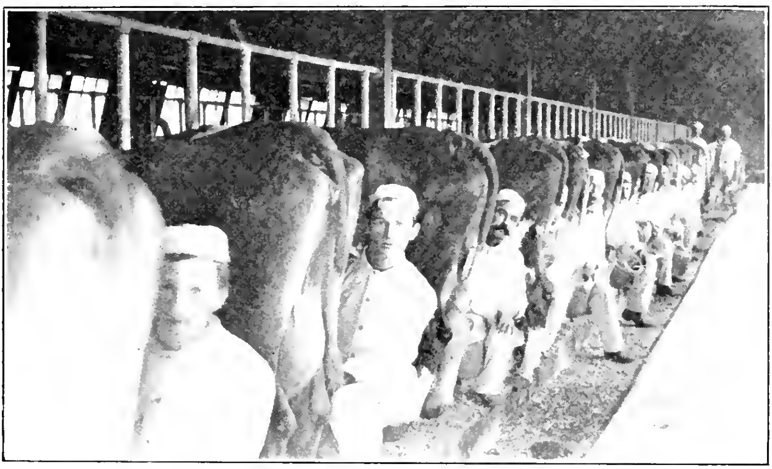


PHOTOGRAPH 5

Milk is secreted from the mammary glands in a sterile condition, that is to say, germs are totally absent. When the milk is discharged from the glands and enters into the cistern—the large reservoir—of the udder, some bacteria gain access; these having invaded the udder from the outside through the teat duct, a small canal in the teats through which the milk is withdrawn. The number of germs entering here is relatively small, however. The large numbers usually found in market milk enter during the process of milking and are the result of multiplication during transportation and storage, unless the milk is kept at a temperature below 40° F. No matter how careful the milker may be, some germs are bound to enter. It is therefore necessary to cool the milk rapidly after milking and keep it cold until consumed. We have then to consider chiefly two points in the production and handling of milk, first cleanliness in all manipulations and cleanliness of all utensils, and second rapid cooling and storage or transportation at low temperatures.

Milk is the natural food for all mammals and each species of mammal produces a milk of such composition as is most suitable for the young of the species. The composition of cat's milk differs from that of

cows, dogs or man's. Some animals produce milk which contains ten times as much fat as is contained in cow's milk. Thus we find proper adaptation in nature of the only suitable food for young mammals. Again, the composition varies in individuals of the same species or race, and during the period of lactation. As the young grow older the concentration of the milk increases. When the calf begins to suck its mother's milk the milk is of thinner consistency than after the calf is several weeks old. It is evident from this fact that, when we substitute cow's milk for human milk as food for infants, the relative increase of milk components is not proportionate to the growth of the infant, but to the growth of the calf. It is, therefore, preferable to feed infants with mixed milk from a herd of cows rather than from an individual



PHOTOGRAPH 6

cow. In a herd we have cows in various stages of lactation and the mixture of milk results in a uniform product, which can be modified if this is desired. Practical experience has proved that the composition of milk obtained from a herd runs nearly the same from day to day.

It is well known that there are differences in composition between cow's milk and human milk. In human milk there is more butter fat and more milksugar. The nitrogenous part, that is, the part which is necessary to replace the cells of the body and enable development to take a normal course, is about half the amount in human milk as compared with cow's milk. The quality of these components is also different in the two kinds of milk. The protein of cow's milk consists chiefly of two parts, one is casein, the other lactalbumin. The latter is more readily digested than the former, but is present in small proportion. Human milk contains less casein and more lactalbumin than cow's milk, and

consequently is more suitable for the food of infants. The fat in human milk is more finely distributed than in cow's milk, which also enhances digestion. Jersey cows furnish milk with a fat content nearly the same as human milk, but the fat globules are larger, and therefore Jersey milk is not as suitable for infants as milk from Shorthorns or Holsteins. The latter breeds produce milk with less fat than Jersey cows, but the globules are smaller.

It is obvious that human milk is the only perfect food for infants. If it is necessary to find a substitute we must be careful to select milk from cows whose product comes as near to human milk as possible. Here again it must be emphasized that mixed milk from a herd consisting of cows of different breeds, and in different stages of lactation, is the best milk to use. It is true that infants can adapt themselves to the use of a different milk from the one designed for them by nature, and it is fortunate that this is so. Cow's milk is the only available substitute for human milk. In some countries goat's milk is used, but this offers no advantages, and some disadvantages. Mare's milk or ass's milk is nearer in composition to human milk than other milks, but is difficult to obtain. Cow's milk serves the purpose very well, if it is derived from a mixed herd and obtained under cleanly conditions.

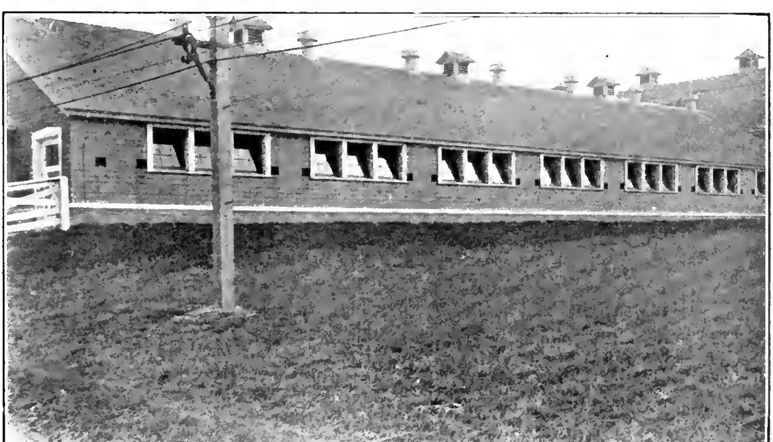
The essential points in producing healthful milk are to observe cleanliness in the process and to cool the milk rapidly and keep it cold. The result of a tendency to comply with these demands has been the establishment of dairies where milk is produced on scientific principles. The cows must be fed with wholesome fodder, must be kept clean and be in perfect health. Tuberculosis is detected by the most rigid test known, the application of tuberculin. This method shows the presence

Photograph 7

of tuberculosis even in initial stages. The stables are constructed with cement floors, with plenty of windows to admit light, and with effective designs for ventilation. Accompanying photographs, taken in model dairies, will illustrate the points under discussion. Photograph 1 shows one side of a sanitary barn with properly constructed windows, which open from the top and admit fresh air, and a carrier to remove the manure. A carrier of similar nature is used for bringing in the food, as shown in photograph 2. By the use of these carriers the handling of food and refuse is reduced to a minimum, and the raising of dust largely avoided. Photograph 3 shows stanchions of approved style, which allow the animals to be comfortable without being cumbersome. They are made of iron pipe, painted and easily kept clean. Photograph 4 shows the center aisle. The cows face each other to encourage cheerfulness. The mangers are also made of cement. Photograph 5 shows washstands, which should be present in all cow barns. The milkers wash their hands frequently so that the dirt from their hands is not mixed with the milk. The milkers should wear clean white suits, as is shown in photographs 6 and 7. The outlets of foul air and the tilting windows are shown to advantage in photograph 8.

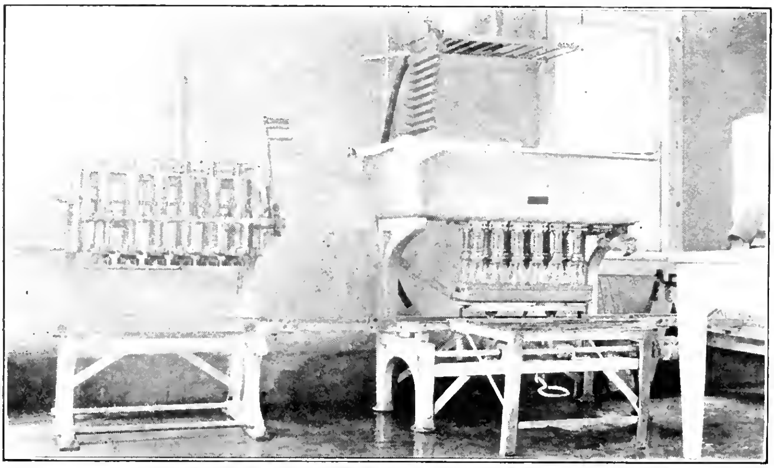
In sanitary dairies the milk is transported to a special room in which it is cooled and bottled. In photograph 9 a cooling apparatus is seen above the collecting tank and on the left-hand side of the same picture is seen a machine which places the pulp caps on bottles.

Market milk contains hundreds of thousands of bacteria per cubic centimeter, sometimes even millions. When only such milk is obtainable it should be pasteurized. Pasteurization is a process by which milk is heated to 140° F. for thirty minutes. This treatment kills about



PHOTOGRAPH 8

99 per cent. of all bacteria and makes the milk safe. Especially is pasteurization desirable when there is danger of disease germs entering the milk. Such disease germs may enter from the hands or clothes of employees in the dairy, also in certain cases from diseased cows. Pasteurization has many advocates and many opponents. Without going into a detailed discussion of the arguments, it may be stated that the process is gaining favor with sanitarians and recent scientific research has shown that the disadvantages claimed against pasteurization are groundless. Epidemics of typhoid fever, of dysentery, of diphtheria, of



Photograph 9

scarlet fever have been spread by milk in many instances and we know with certainty that the germs causing these diseases are surely killed by efficient pasteurization. It remains with boards of health to control pasteurization, so as to insure its efficiency. For this purpose the milk should be examined before and after pasteurization. If the milk is obtained from careless producers, it should not be permitted to be used under any conditions. If the producer can show fair conditions the milk should be pasteurized.

If, however, milk is produced with the refinements outlined above, pasteurization becomes superfluous. Many dairies produce milk with less than 10,000 bacteria per cubic centimeter, some as low as 1,000. By extreme care and intelligent supervision such milk is not much more expensive than ordinary market milk and the outcome of the war waged against poor milk supplies will probably bring such milk within the reach of every one. This milk is generally known as certified milk, because it is certified to by a body of responsible medical men, who employ experts to examine the milk at stated intervals and inspect the

dairies, so as to insure safe methods of production. The conditions expected from the producer are rigorous, and consequently this certified milk costs more to produce than other milk. Unfortunately most of the dairies producing this excellent milk are heavily capitalized, but in some instances milk which is above reproach is produced at dairies with investments of $1,500 to $2,000. The essential point is efficient and constant supervision.

On the whole the solution of the problem of city milk supplies lies largely with the consumer. The consumer must be willing to pay a careful dairyman for his work and investment and when we remember that a quart of milk contains as much food, and readily assimilable food, as a pound of beef, and if we compare the cost of the two articles, we can not but admit that milk is a cheap food and a safe food if produced and marketed under proper precautions.

A FLASH OF LIGHTNING

By Professor FRANCIS E. NIPHER
WASHINGTON UNIVERSITY, ST. LOUIS

IT is customary to classify lightning discharges into at least two classes. This classification is based on the appearance of the flash. One kind of lightning is called forked lightning and the other sheet lightning. There has been some discussion concerning sheet lightning, it being claimed by some that it is merely an illumination due to a discharge which is hidden from view.

The real fact appears to be that both ends of a lightning flash are usually hidden from view within the two clouds. One of these clouds contains falling drops of water which are overcharged with the negative corpuscles which atoms of all kinds of matter contain when in normal condition. The other cloud contains drops which have less than the normal charge. This cloud has always been said to be positively charged.

The writer has sought to obtain photographic evidence of the conditions within these two clouds, at the instant when the discharge

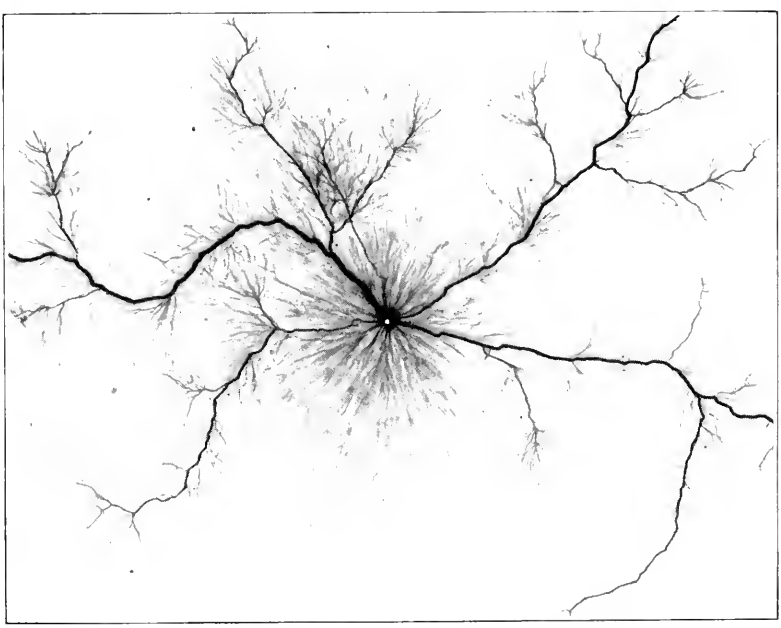


Fig. 1. The Overcharged Cloud. An inflow of the negative fluid to the main discharge channel, whose end is seen at the middle of the plate.

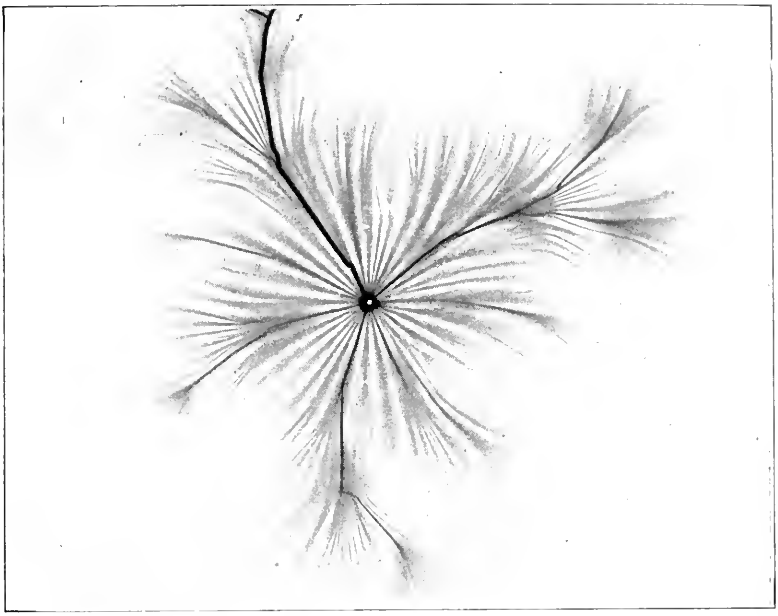


FIG. 2. THE OUTFLOW INTO THE CLOUD WHICH HAS LESS THAN ITS NORMAL CHARGE.

occurs. This evidence is presented in the figures, which are reproduced from photographic plates.

Fig. 1 represents in cross-section the cloud which is overcharged with the negative fluid. The cross-section is at right angles to the end of the long flash which connects the two clouds. The discharge lines on this plate resemble a system of rivers and tributaries, which penetrate the cloud. These drainage lines elongate up stream. Some of them are sharply defined. Others, for reasons which will be explained, are seen only in shadowy outline.

Before the flash occurred, the falling drops, which were all highly charged, repelled each other. After the discharge those drops which happened to lie in the path of some one of these tributary discharge lines, have lost their overcharge. There is then an attraction between such drops and those which were slightly outside of these drainage lines, and which are therefore still overcharged. These two groups of drops are intimately commingled, as is shown by the intricate nature of the system of drainage channels. As they continue their fall to earth, they coalesce, and a brief dash of unusually large drops of rain is observed.

The discharge pours through the long hole in the air, in which the conditions are like those which exist in a vacuum tube. The conditions which exist in the cloud at the other end of the flash are shown in Fig. 2.

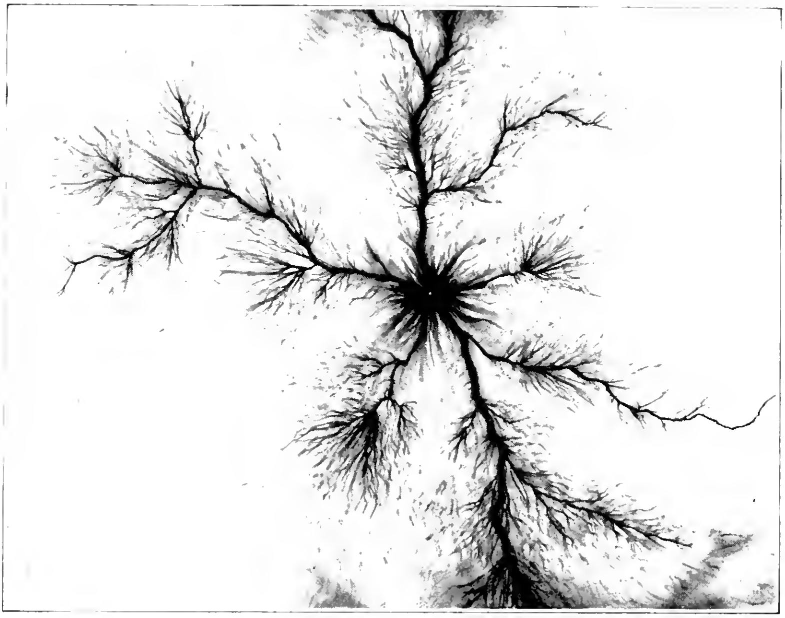


FIG. 3. AN INFLOW AS IN FIG. 1.

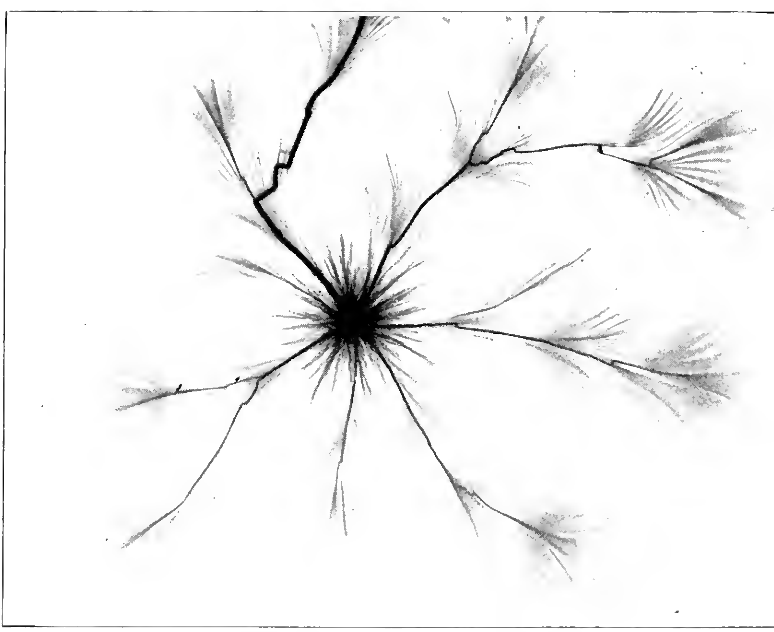


FIG. 4. AN OUTFLOW AS IN FIG. 2.

Here we have a representation of the outflow into the cloud which has less than its normal charge. The flash here diffuses into the cloud, and the outer portions of the flash might well be called sheet lightning. The conditions which would bring about the brief dash of large raindrops do not appear to exist at this end of the lightning flash.

Figs. 3 and 4 are similar to Figs. 1 and 2, the discharge being somewhat more violent, or greater in quantity. In Fig. 3, it may be seen that the inflow in some cases begins at isolated points, and progresses inwardly towards inflow lines which are elongating in a direction opposite to that in which the flow is taking place.

If these discharge figures are to be described in the language of the two-fluid theory, Figs. 1 and 3 must be called an outward positive discharge. Figs. 2 and 4 must be called an outward negative discharge. We must say that the outward negative discharge shown in Figs. 2 and 4 came from the cloud represented in Figs. 1 and 3, and that the outward positive discharge, shown in Figs. 1 and 3, came from the cloud represented in Figs. 2 and 4.

Such an explanation seems so essentially absurd in the presence of these photographic plates, that it will not be urged.

In conclusion, however, a confession must be made. The lightning discharge here described was artificially produced. A plate-glass machine, with metal conductors terminating in pin-heads took the place of the long flash of lightning. The pin-heads rested upon the centers of the two photographic films, the plates resting on large sheets of glass. There were small spark-gaps of about half an inch in each line, at the machine terminals. A single spark across these gaps produced a glow over the films around the pin-heads. In order to bring some of the discharge lines down into close proximity to the films, so that they would be sharply defined, copper plates were placed under each photographic plate below the sheet of glass. These copper plates were grounded or, what produces the same result, they were connected with each other. No trace of the discharge can be detected until the photographic plate is developed. With this confession, and with an apology for having misled the reader, the question may be asked, can any one look at Figs. 1 and 3 and believe that they are produced by an outward discharge of positive electricity? These plates tell their own story. They represent an inflow of negative corpuscles, along drainage channels.

Some of the lines are not sharply defined. They are too far above the film. They all present a shadowy appearance, if the condenser action of the copper plates is eliminated.

COLLECTING ON A CORAL REEF

By Professor VERNON L. KELLOGG
STANFORD UNIVERSITY

ONCE every three weeks a 6,000-ton steamer leaves San Francisco for Sydney. You sail with it six days from gray and cold water to warm and blue, and touch at Honolulu. They let you off for tiffin with *poi* "cocktails" in a hotel hanging over the sliding surf on wondrous Waikiki. You make the swift drive up the showery Nuuanu Valley past the tombs of the Kamehamehas and the flower gardens of the *lei* sellers, to the Pali, where you look over the ridge of the island and see the ocean on the other shore. Then you come back and reembark. Six days more—due south these days and the water all blue and the days all warm and the equator crossed on the fourth day—and you whistle hoarsely in front of a lone mountain towering out of the tropic ocean. Then, as you have knocked, you move slowly in at the open door of a great water-filled bowl, which is simply the yawning crater of a dead volcano that makes all there is of Tutuila, a microscopic island appanage of these imperial United States.

The sides of this bowl, which are the inner faces of the crater, lift swiftly for two thousand feet above the water, and are all clothed and made soft by the velvet-seeming tropic bush that clings to every climbing yard. Around the water's edge runs a narrow strip of gleaming coral sand, and here are the toadstool native house and the white government buildings of the port village, Pago-Pago. Here too are the dense, dark-green heads of bread-fruit trees and the gently curving, lazily swaying, slender trunks of cocoanut palms holding up their heavy feather-duster tops. And along this beach stroll the loafing, chattering, friendly Samoans with their naked shoulders shining with fresh anointment of odorous cocoanut oil and loins encircled with the gaudiest of *lava-lava*. For this is steamer day, and there are unsophisticated, globe-trotting, amateur antiquarians to be sold ancient war clubs to,—clubs hastily whittled out and dented and smoke-blackened since our hoarse whistle sounded before the crater's gate.

But for our coral-reef collecting we are going to the larger German island, Upolu, with its harbor town Apia, made memorable by the great hurricane of '95 which turned warring factions of English, German and American sailors on warships and Samoan braves on shore into common savers of one another's lives. The children of nature showed their God-head in that terrible day and night, and the republican presi-

dent of eighty millions of people did no more than recognize the brotherhood of man when he sent Seeumanu, sturdy, half-naked chief of a few hundred brown barbarians, the gift of a rich boat to commemorate the day of revelation.

Now Upolu, whereon sits Apia, is about eighty-five miles away from Pago-Pago on Tutuila where the American steamers touch, and so we must descend from the high decks of our 6,000-ton Sydney packet to the spray-wet planks of the *Kawau*, inter-island messenger and carry-all. I had long had my misgivings about these last eighty-five miles of our ocean voyaging from San Francisco to the Samoan reefs. And these misgivings were not abated when I ventured to ask the captain of the *Ventura* something of the figures, as to tonnage and knots, of his little ocean sister, the *Kawau*. Quietly and unexplosively he expectorated over the gunwale of the upper deck where we stood.

"Sir, if the *Kawau* were alongside I could spit into her funnel from here," said he. Inelegant, perhaps, but sufficiently expressive to give me forthwith a symptom.

It was even so. Thirty-five is the *Kawau's* tonnage figure. The boats that the bare-legged Paris children sail in the round pool of the Tuileries gardens look larger and roomier to me than the *Kawau* as I recall these two types of vessels now. But our reef lay eighty-five miles away across the heaving swells of a trade-wind irritated ocean. And the *Kawau* was the only boat going our way. So we transshipped. Boxes and bags went into a tiny cavity amidships called cabin. We sprawled *faa Samoa* (native-wise) on the salt-encrusted deck. My own seat was a coil of tarry rope on the stern grating. As the swift tropic twilight fell we issued from the harbor's mouth and rode full tilt against the first great swell. All night were we a-jousting. We had, from the start, hardly any symptoms. It all looked too dangerous to waste time or handicap oneself with seasickness. The soft tropic night wore on, while we momentarily expected the apparently certain overwhelming. Far in the middle of the long dark hours, as we slid about on the slippery deck, face to the strange new star pictures of the southern sky, the captain came aft, surrendering the wheel to a native roust-abou—ah, quartermaster, and, opening a microscopic cellular deck-closet, went in, leaving the little door ajar. Soon streamed out a fitful light and the extraordinary sounds of a cheap gramophone, singing "Lead, Kindly Light"! Even the captain had apparently lost all hope!

With the first soft gray light of morning we stared hard to port where land should lie. Soon the lifting shores of Upolu took form. We nosed through a narrow opening in the fringing reef and hove-to in a shallow bay bordered shoreward by a flat crescent of white sand beach. Along this beach we could pick out, in the swiftly growing light, the low white houses of Apia. Behind the houses was the dense green mass

of the tropic bush sloping upward and broken here and there by the towering even lines of the great cocoanut plantations. Still higher rose the volcanic ridge and peaks that make the roof of the island. The nearer of these forest-covered peaks, lying immediately behind Apia, is Mount Vaea, Stevenson's mountain. On a shoulder of this dark green mountain is Stevenson's grave, with its low, flat tomb like those of the Samoan chieftains. And under this grave-crowned shoulder, lying beautifully in a little open space amid tall trees, is Vailima, the house of the five streams. There are no longer five streams there, but only two, which come trickling down the long hill slopes to pour their slender threads of fresh water into Apia harbor.

A bustling German customs house officer clambered aboard and we went through the formalities of civilized travel. They were less irritating than usual, and soon we were free to choose among the eager naked-backed boatmen that clamored in the water about us like sea gulls quarreling over ship's refuse. Waiula, old grizzle-haired, strong-faced, sinewy-armed Waiula, claimed us by virtue of his special insistence and our natural deference to age. We rowed in past the great rusted hulk of the German warship *Adler,* lying beached on the reefs, conspicuous relict and reminder of the awful hurricane, and made our way, sleepy-eyed, exhausted and despondent to a two-story frame building on the beach, conspicuously labeled "Tivoli Hotel." Here we sat, silent and helpless, until coffee could be made. With coffee and breakfast and a morning nap, the world was new again and we turned our eager attention to the problem before us, that of getting acquainted with the life of the coral reefs.

The islands of the Pacific are of two types; either all made of coral, or mostly made of volcano with fringing coral reef. Indeed the "all coral" islands are only so on top, for they are simply volcanoes whose summits do not project above the water's surface, but do come near enough it to support a persistent coral growth. This builds up on its volcanic support an atoll or islet rising a few yards above the ocean level. The more striking and beautiful islands are volcanic peaks which lift their great masses for four or five, seven or eight, even for thirteen or fourteen, thousand feet above the water. Most of these volcanoes are dead, but some are alive, as Mauna Loa on Hawaii and the recently re-opened and still flaming volcano on Savaii of the Samoan group. But practically every volcano island has its coral reefs, either fringing or barrier or both. Like a ring of Saturn the flat-topped band encircles the volcano's waist at the ocean surface, and in the shallow waters and innumerable pools on the reef the naturalist finds a rich collecting ground. We paid close attention to the tides, and every day the ebb would find us working on the half-exposed reef, prying into crevices, breaking up dead coral masses, wading the green water, and ever scrap-

ing intimate acquaintance with uncouth crawling things of the sea, made visible for an hour in their shallow prison pools. Not all uncouth, either, for of marvels of color and pattern, bizarre and beautiful, there was never lack.

In echinoderms, that is, star fishes, brittle stars, sea-urchins and sea cucumbers, the Samoan reef is very rich. I think we took some two dozen species. An abundant star fish is ultramarine blue, with slender, smooth-surfaced rays. A curious large, reddish-brown, ugly-seeming kind has heavy coarse spines an inch or more long, scattered over it, and these spines sting. Many specimens of the brilliant blue star fish were found with arms slightly or badly mutilated, but all regenerating. I have some specimens by me now which show that even a part of a single arm can regenerate all the rest of the body, that is, a new disc and four new arms besides the remainder of the single mutilated arm.

Of slender-rayed brittle stars there are brown and green and mottled sorts, some with white cross bands on each arm, and all with the fragile arms breaking away with the least roughness in handling. Often merely the contact with the preserving fluids seems to be sufficient for a general epidemic of arm-shattering. Among the sea urchins a kind with very slender, long, almost needle-like spines is abundant. These spines are not only sharp, but stinging, and often a warning tingle told the exploring hand in crevice or pool bottom of the presence of this well-protected little urchin. Another slender-spined sort has white bands around each spine, so that the thickly beset body is black-and-white barred. A larger kind has its heavy spines each encircled by two or three rings at small distances apart. Still a larger species shows heavy, thick, blunt spines much like miniature baseball bats.

We were not the only sea-urchin collectors on the reef. With each low tide would come forth a score or more of natives, mostly half-clad women and children, who would wade about in the shallow water of the reef and among the scattered pools collecting choice tit-bits for an evening feast. Among these morsels a certain sea-urchin seemed to be favorite. Often the collectors could not restrain their appetites and would crack open the brittle tests, and suck out and swallow raw some choice inner part.

The sea-cucumbers were very abundant; they lay scattered over the whole reef top, in some places one to every square foot. A large greenish-black form about ten inches long, with four-sided body, and unusually firm body wall with short blunt tubercles; a soft-skinned dark-brown form about six inches long when not extended, but capable of great extension, found between tide lines under stones; and a small spotted brown and white kind three to four inches long, were the three most abundant species; but several other kinds were common, among them a small black knobby sort, the real *beche de mer* of the Samoans.

Collecting sea-cucumbers is easy, but preserving them is not. Rough handling of any sort and above all the plunge into the preserving fluid inevitably caused the cucumbers to eject from the mouth opening a considerable portion of their insides, comprising most of the esophagus, stomach and intestines. This extraordinary behavior tended both to ruin the specimens and to make a rather messy lot of preserved material. Occasionally not only cucumber stomach would come out, but also an active and astonished little live fish. This fish, called *Fierasfer,* seems to have adopted for more or less permanent home the inside of sea-cucumbers. It is a slender, active, bright-eyed little creature which has certainly displayed an extraordinary cleverness in the life-and-death game of hide and seek with its enemies.

Octopuses and squids came to be familiar acquaintances in the reef pools. None of these were large, the pulpy, sack-like body of the largest octopus found being perhaps not more than a foot long, with arms of twice that length, but with its staring eyes and hooked beak and sucker-armed tentacles even a small octopus looks very ferocious and capable of making serious trouble. The squids with their power of ejecting a dark fluid, discoloring all the water in the pool so that nothing could be seen in it, had the further protection of concealment. We scientific collectors were hard pressed in our search for octopuses by the food-hunting natives. These devil-fish are much sought for by natives and are reputed to taste, when cooked, much like chicken. The most effective way of rendering the octopus harmless and helpless in its collector's hands is that of turning it inside out, which is a means regularly practised by the natives. It seems to require, however, a particular knack which we never learned.

There were, of course, hosts of crabs, little crabs, middle-sized crabs and big crabs; red and green and polka-dotted. Rather frightening at first were the active, foot-long *Squillas* with sharp knife-blade claws. Even more terrifying was a specimen (brought to us by a native) of the great cocoanut crab, *Birgus.* These tough customers have a body seven or eight inches across, and great long strong legs extending a foot on either side. Their shell was of the hardest and their grasping claws of the strongest. They spend most of their time in the cocoanut plantations, feeding upon the fallen nuts. Just how they get at the tender meat inside the cocoanut shell is more or less a question. The natives tell you that the great crab climbs a cocoanut tree, snips off a cocoanut, thus letting it fall heavily three or four score of feet to the ground. It perchance falls on a stone, but even if not it is likely to be broken, anyway. The crab, descending, then tears open the cracked shell and scoops out the rich food. Perhaps this extraordinary crab does this thing. We never saw it. But that it feeds upon cocoanuts is quite cer-

tain. Its flesh is much prized for salad and has a distinct flavor of the nut.

Of the multitude of reef-inhabiting shells and their variety one can not even venture to speak. The natives use many of the smaller gasteropod shells in making necklaces. Often these little shells are strung alternately with red or yellow seeds. The many cowries attract attention, particularly a small white one with light-brown black-bordered ellipse which is the most abundant shell on the reefs. A large fluted shell, called by the Samoans *faigua,* is not uncommon, and its flesh is eaten raw by the natives. Many of the shells housed active little hermit crabs, and as we worked about the pools there was a continuous rapid scuttling about of these strangely tenanted houses.

Less familiar animals were the various marine worms, brilliantly colored nudibranchs and the unsavory looking fleshy masses of large pteropods. One of these salt-water worms looked almost exactly like the familiar fuzzy brown caterpillar of the Isabella moth that scurries about across our sidewalks and pathways in winter time. The most extraordinary, as well as the most famous, worm of the Samoan reefs is that curious creature called the palolo, which with a certain phase of the moon in November of each year appears in myriads in the shallow reef waters and is gathered with feverish haste by the natives as the choicest food of the whole year's finding. To be accurate, they are not the worms themselves which thus appear, but only certain parts of the worm body, the egg-producing parts, which break off from the rest of the worm, lying in crevices in the reef far below the water's surface. Mayer has recently described the similar habits of an Atlantic palolo common on the Dry Tortugas.

As for the "coral insects" themselves, they have been so often pictured and so much written about, that their graceful shapes and marvelous colors are familiar to all readers. As a matter of fact, we saw curiously little of live coral, and that which we saw was by no means brilliantly colored. The live zone of a coral reef is that part on its outer or seaward margin where the surf is always breaking and the water is pure and clean. The great mass of the reef is composed of dead coral, the shattered, crushed and compacted lime skeletons of millions of dead individuals, and this rock mass, this limestone ledge, is of dirty grayish or brownish white with no beauty of color at all.

Where we did see all the marvel of color and pattern that one must find on a tropic coral reef, or be sadly disappointed, was in the deeper, larger pools near the seaward edge of the reef. Imagine all the most brilliantly colored and strangely patterned tropic butterflies that you have ever seen pinned up in dead rows in museum cases alive and disporting themselves in clear water! You have before you then in your mind's eye no more extraordinary or beautiful sight than that actually

afforded by the butterfly fishes of the pools of the tropic coral reefs. Robin's egg blue and indigo, green and cadmium yellow, red, brown and softest rose, scarlet, crimson, magenta, lavender and royal purple, pink, salmon and tawny—all these colors laid on in dots and spots and splashes, in lines and bars and polygons, and you have the paints and the painting of the fish harlequins of the pools. Flashing back and forth, lurking under projecting stones, rushing into dead coral heads and coming reluctantly half paralyzed to the surface as we used the collector's favorite methods, this display of fantastically colored fish life was the most conspicuous feature of each day's seeing.

Off the reef in the deeper water were larger fishes and many of them too also extraordinarily colored and patterned. The parrot fishes with their blue and green ground color and their livid pink and salmon and rose markings were every-day prizes of our divers. The taking of the off-shore fish (in water from two to six fathoms deep) had an element of excitement in it. Small dynamite sticks were exploded in the water to stun the fish and make them easily captured by the naked divers. In one end of a small, wobbly canoe would stand a native with a dynamite stick in one hand and a slow-burning piece of wood, or better, a lighted cigar, in the other. Leaning down backward in the extreme other end of the canoe would be the naturalist! When we reached a good position he would light the short fuse of the explosive and holding it almost to the last moment before explosion (much as a boy holds on to his big firecracker on Fourth of July mornings) he would hurl it overboard. The explosion would take place a few feet under water, and on the moment in would plunge the active divers from a second canoe. Altogether, in our short two months collecting, we took more than five hundred species of fishes from the reefs and shallow adjacent waters of the two Samoan islands. Of these fully one hundred are species hitherto unknown to naturalists.

Of the long, glowing days under the ardent southern sun; of the soft, odorous tropic nights; of the feastings and council meetings with the friendly, hospitable natives; of our glimpses between working hours of the lotus-eating life that makes even the shortest stay in the tropics a fascinating memory and that leaves an ever-persistent longing; of all this there is no space for even a word. We have only now to pack our boxes and specimen cases, to send a stirring petition to the Commandant at Pago-Pago to save us from another ocean trip in the *Kawau* by sending the American gunboat for us, and to make final transshipment to the great Sydney-San Francisco liner, to make an end of our summer's work and play.

THE ORIGIN AND CONTROL OF MENTAL DEFECTIVENESS

BY DR. CHAS. B. DAVENPORT

STATION FOR EXPERIMENTAL EVOLUTION, CARNEGIE INSTITUTION OF WASHINGTON.

NOT long ago I spoke to a company of physicians and lawyers on inheritance of certain types of imbecility, and exhibited some charts that showed that imbecility in a child is due to defects in the germ-plasm of both his parents. At the end of my remarks the chairman pointed out that the facts presented merely deferred the origin of feeble-mindedness a generation or two and did not touch on its true cause. I find this idea wide-spread; the point raised consequently deserves further consideration: How did feeble-mindedness originate in the first instance?

Before we can answer the question as to the "cause" of feeble-mindedness it is desirable to get a clear definition of the term. As a matter of fact, very diverse definitions have been offered. An old legal formula is as follows: "He that shall be said to be a sot and idiot from his birth is such a person who can not count or number twenty pence, not tell who was his father or mother, nor how old he is, so it may appear that he hath no understanding or reason what shall be for his profit or what for his loss; but, if he have sufficient understanding to know and understand his letters, and to read by teaching or information, then it seems he is not an idiot." While this definition lacks in completeness and scope, it has a more philosophical basis than many that are more recent. Of late the Binet-Simon tests of mental grade have aroused new enthusiasm and have been thought to give an exact, quantitative measurement and definition of the different classes of mental backwardness. The method is simply that of establishing a series of mental standards (questions, exercises, mental feats and so on) for each year of school life, grading a given subject by these standards and finding the difference between the actual age of the subject and the standard age of the highest test passed by him. This method of defining feeble-mindedness seems to assume that there is a greater mental resemblance between two persons deficient three years than there is between one who is deficient three years and one who is deficient four years. And that, it seems to me, is fundamentally erroneous. For the modern biologist is coming to rely less on the idea of races or groups and to realize that, in nature, we have only individuals, made up of collections of traits that are, for the most part, separately inheritable. Not individuals, but their transmittable characters, are

the units of heredity. From this point of view we may say that feeble-minded persons are such as lack one or more mental traits that are socially important.

From this definition it follows that mental defectives differ quantitatively in the number of socially important traits that they lack and qualitatively in the kind of traits and the degree of their social importance. Defectiveness in one important trait only may be called uni-defectiveness; in two traits, di-defectiveness and so we may have tri-defectiveness up to multi-defectiveness. For example, cases are well known of number-defectiveness, attention-defectiveness, memory-defectiveness, imagination-defectiveness, emotion-defectiveness, inhibition-defectiveness, moral-defectiveness, occurring quite without other defects. Well-known unit defects are word-blindness, figure-blindness, word-deafness, tone-deafness and color-blindness. Any of the defects may occur isolated or two or more of them together in one individual. Such defectives are often not recognized as such, if the missing trait or traits have little social importance; but if gentleness gives way to cruelty or self-restraint to self-indulgence the uni-defective becomes a "moral imbecile," and such a moral imbecile may be good at his school work and bright and active in most ways. It is, however, the multi-defectives that constitute the main problem of the feeble-minded; for they are fairly common and are a constant drag on that school system which is not adapted to their capacities. Yet among such may be good mathematicians, musicians, mechanicians, etc. It is clear, then, that "feeble-mindedness" is not a simple trait, but a convenient group in which to put all of the socially inadequate.

Can we, in the midst of this heterogeneity find any general "cause" of defectiveness in its varied manifestations? It seems to me we can discover such a cause by attending to various features of defectiveness. First of all we have to recognize that these defects are in general *hereditary*. There are family strains with color-blindness, stuttering, word-blindness, number-blindness, tone-deafness, and so on. The deficiency of the uni-defective comes from a defect in the germ-plasm of one or both of his parents. In a multi-defective, likewise, all the absent traits are the result of corresponding defects in the germ-plasm of the parents. And if both parents be multi-defectives that combination of germ-cells will be rare indeed that results in anything but a feeble-minded child.

And, secondly, it is to be observed that "defects" are not pathological conditions; they are merely deviations from the normal condition of the adult. For every person shows these defects at some stage of his life and only gradually overcomes them. My nine-months-old son can not talk, nor dress himself, nor attend to his animal needs. He is

word-blind and figure-blind. He is cruel to the cat, appropriates to his own use the property of others, and insists vehemently upon having what he wants at whatever inconvenience to another. He is now a low-grade imbecile without moral ideas. He will prove himself not to be "feeble-minded" if, as he approaches puberty, all of these and the other socially important undeveloped conditions prove, under fair culture, capable of development up to the corresponding "normal" conditions. Defectiveness is thus a persistent infantile condition of one or more characteristics; a failure of certain socially important traits to develop.

Now there is a well-known biological principle that "ontogeny recapitulates phylogeny"—that the child in his development passes through the same series of physical and mental stages that the adults did in the successive generations of the race's development. So we may infer that man's remote ancestors did not go in their adult stage beyond the point where this infant-man is now. Indeed, the adult apes, nearest allies of our ancestors, show the same inability to talk, to dress, to regard property rights and to be gentle and considerate toward others that the infant shows. And we can not escape the conclusion that the gradual acquisition of social traits by the normal child follows much the same road as the evolution of social man from non-gregarious apes. But, there are men who never develop these social traits. And if we study the pedigrees of such men carefully (and many of them have been studied for six or seven generations) we trace back a continuous trail of the defects until the conclusion is forced upon us that the defects of this germ plasm have surely come all the way down from man's ape-like ancestors, through 200 generations or more. This germ plasm that we are tracing remains relatively simple; it has never gained (or only temporarily, at most) the one or the many characteristics whose absence we call, quite inadequately, defects. Feeble-mindedness is, thus, an uninterrupted transmission from our animal ancestry. It is not reversion; it is direct inheritance.

To summarize: Man is evolving and in that evolution he has lost some physical traits and gained some mental ones. But neither in their losses nor in their gains have all strains evolved to the same extent. Some races have lost the skin pigment, but others have made little progress in this direction. We are getting rid of our body coat of hair, but the Akkas of the Upper Nile and special smaller strains have a very hairy body, and so appendix and tail (coccyx) show variations that run in families. Likewise in the acquisition of mental traits, whole races differ in their ability to speak, to count, to foresee. The Ethiopian has no more need for thrift than the tropical monkey and has not acquired it. It is not surprising that there are strains, even

such as have a white, hairless skin, that have never acquired an appreciation of cause and effect, of the importance of controlling the sex-passion, of the necessity of regarding the rights and feelings of others. The marvel is not that these strains still persist, but rather that they have been so nearly exterminated.

This brings us to the subject of the control of mental defectiveness. We see at once that there must have been at work, even in prehistoric times, a sort of natural control by the elimination of those incapable of meeting the ever-increasing complexities of "advancing civilization." As man spread to the north those strains that had not acquired the trait of hoarding for the winter mostly perished of cold and hunger; those strains that had not acquired the sense of property rights and tended to invade the stores of others were always in danger of being cut off. In England, less than a century ago, there were 223 classes of offences punishable by death. Under such rigid selection "defective" ancestral strains tended to be eliminated.

To-day, in our most highly civilized countries, the process of elimination of the unfit animal strains is largely reversed. We protect, in an institution, the members of a weak strain up to the period of reproduction and then let them free upon the community and encourage them to leave a large progeny of "feeble-minded"; which, in turn, protected from infantile mortality and carefully nurtured up to the reproductive period, are again set free to reproduce, and so the stupid work goes on of preserving and increasing our socially unfit strains.

But a reaction is setting in. The legislatures of six of the United States have already voted to permit the sterilization of defective persons. But it is doubtful if the "more advanced" public is altogether ready for such operations. A less drastic, but not less effective, method is the segregation of the defective strains during the entire reproductive period. However, the method is not so important, but in some way or other society must end these animalistic blood-lines or they will end society.

THE ACADEMY OF SCIENCES, PARIS, FROM 1666 TO 1699

By Dr. EDWARD F. WILLIAMS
CHICAGO

THE account of the Paris Academy of Sciences, one of the five organizations which together form the French Institute, is found in its *Mémoires,* and in the history of the academy published in 1733 of which the portion written by du Hamel, the first secretary, was in Latin and covered the years from 1666 to 1679. This history was continued in French by M. de Fontenelle, du Hamel's successor, to nearly the end of the year 1699. An edition of this history in five volumes was published in Holland in 1740, but those who wish for absolute accuracy should consult the *Mémoires* published at Paris in 1740. Of these *Mémoires* there were forty volumes. The history of the old academy, which covers very fully the period from its reorganization in 1699 to its abolition by the revolution written by L. F. Alfred Maury, a member of the institute, published in 1864 by Diderot freres, though trustworthy, and very valuable, is far from easy reading.

During the first half of the seventeenth century, a literary man was expected to be a scientific man also, or at least to possess a general knowledge of scientific principles and of the discoveries which scientific men had made. Descartes, for example, was a physicist, a mathematician and a philosopher. Specialization began in the eighteenth century with men like Buffon. Not long after the middle of the seventeenth century there grew up a feeling in the more cultivated circles that something ought to be done to increase the honor shown scientific men, and to make better provision for their work. Although science was in a more advanced condition in several other countries than in France, France was behind no one of them in her efforts to organize her scientific forces and render them of value to her people. As the "Historians' History" (Vol. XI., p. 637) says: "The seventeenth century was one of the great scientific ages of humanity. It saw the birth of analytical geometry and of the infinitesimal calculus, the formulation of the astronomical laws of Kepler and Newton, and the workings of astronomical discovery. It witnessed the first great stride of physics, the progress of optics and acoustics, the invention of the barometer, the thermometer, the manometer, the air pump, the electrical machine; the first rudiments of the steam engine; the first researches on plant life, and the first attempt at botanical classification.

Anatomy and physiology were revolutionized by the discovery of the circulation of the blood, of the chyliferous and lymphatic systems, by the beginning of histology and microscopic research. Medicine made progress in all its branches and was enriched by new medicaments." Much of this was accomplished outside France. "In mathematics the French may place the names of Descartes, Pascal and Fermat, alongside of Kepler, Newton and Leibnitz, but the great Keplerian and Newtonian laws of universal gravitation; the great Leibnitzian theories on the formation of our globe; the astronomical discoveries of Galileo, Huyghens and Helvetius surpassed the work of Gassendi, Picard, Cassini, Bouillaud and Cassegrain. In physics Pascal, Descartes, Mariotte and Denis Papin upheld the French name, but the French have but one zoologist, Claude Perrault, physician and architect, to place alongside with those of Italy, England and especially Holland; in botany, Tournefort let himself be outdistanced by the English; in zoology the French had but Descartes and Maillet; in medical science they had only Pacquet, Duverney and a few skilful practitioners." It is little wonder that Colbert, the prime minister, who was not slow in recognizing this state of things, should seek to change it by bringing the scientific reputation of France up to the level of that of other countries, or that he should take advantage of the treaty of Pyrenees to persuade the king to organize an academy of sciences. In no other way, he believed, could he increase the fame of the king more permanently than by establishing on a firm basis an academy to do for science what the academy of Richelieu had begun to do for literature.

Colbert's first thought was to form an academy which would embrace the most distinguished men in all branches of learning. This was soon found to be impracticable. It might be dangerous, politicians suggested, to discuss historical matters too carefully and earnestly, and as lovers of literature were satisfied to remain in Richelieu's academy only science and art were left for the new academy. There were many reasons why lovers of art and architecture were not represented in the new organization.

Although scientific men had for many years been in the habit of meeting in private houses to discuss questions of interest in science, at first only mathematicians were admitted to the new institution. These were Carcavi, Huyghens (of Holland), Roberval, Torricelli (of Italy), Auzout, Picard and Budt. To this number de la Chambre, physician in ordinary to the king, a physicist and famous as an author, was added. In a short time chemistry and anatomy were represented by du Clos, M. Perrault, Pacquet, Gavant and Marchaut. A few young men were brought into the academy to be trained in the studies it was seeking to advance, that they might be ready to fill vacancies as they occurred. These young men were Miquet, Couplet, Richer, Pivert

and de la Voge. Pensions or salaries were provided for the members of the academy, who were expected to devote their whole time to study and experiment. There was a special fund in addition for experiment. That these men of science might work to the best advantage it was agreed that physicists should meet on Saturdays, mathematicians and astronomers on Wednesdays. General meetings were held every month at which reports were read by Secretary du Hamel of all that had been done. These were in Latin, a language in which the secretary had great proficiency. The meetings were held at first in the Royal Library, but were soon removed to the Louvre, where, save during the interval caused by the revolution, they continued to be held till 1806, when the Institute found a permanent home in the Mazarin Palace. As was said in a previous article, the Paris Academy of Sciences has been regarded in many ways as the most important scientific institution on the continent, if not in all Europe. It has been the model after which many other scientific academies have been formed. Its 68 members are now divided into eleven sections. Five of these sections, viz., those of geometry, mechanics, astronomy, geography and navigation, belong to the mathematical department of the academy; six of them, those of chemistry, mineralogy, botany, rural economy, anatomy and zoology, medicine and surgery, to the department of physics. Care has been taken from the first to fill each section of the academy with the best available men, and, although some first-class men have not found their way into its ranks, yet comparatively few of them have been left without its honors.

It is exceedingly interesting as well as instructive to look over the quartos which contain a description of the work of the academy prior to 1700. Nominally eleven in number, yet as volume three is in three parts and volume seven in two, there are fourteen volumes to be examined. They furnish a clear idea of the state of scientific knowledge at the time when the studies reported were made, and enable one to trace the progress of science in its various departments through more than a generation. In Volumes I. and II. we have a history of the academy with the names of its members prior to 1734 and a list of their publications. Nothing is more attractive to a real student in all these volumes than this list of names and publications. Volume III. contains descriptions of the animals which the academy secured for dissection. Most of them are common animals. The cuts which represent them are fine specimens of the art of the time. A picture of the animal as it appears in life is first given, then follows a cut of the skeleton and such other parts of the body as the dissector cared to exhibit. In the text a description is given of the animal as it ordinarily appears, with all that can be learned about it from classical and other writers. This is followed by a detailed description of its con-

struction. In these descriptions we have the unconscious beginnings of comparative anatomy. In them all careful comparison is made with similar parts in the body of man as well as with the bodies of other animals. Volume IV. contains an essay by M. du Clos on the principles of natural mixtures and observations on the character and location of the mineral waters found in the different provinces of France. Of these waters 67 varieties were examined in addition to the waters of Spa. In an essay by M. Dodort, written as a contribution to the history of plants, careful descriptions are given of many common, and of not a few rare plants. Volume V. is noted for the variety of subjects treated. M. Frenicle explains a method for solving problems by means of exclusion. There is in this volume a brief treatise on right-angled triangles and a table of magic squares. M. Blondel suggests a solution for the four cardinal problems of architecture. But one must turn the pages of this volume for one's self in order to see what subjects interested scientific men during the last quarter of the seventeenth century. In this volume one will find abundant proof of the scientific ability of M. Frenicle. In Volume VI. there are special treatises by M. de Roberval and M de l'Abbé Picard, though the astronomical works of M. Picard are contained in Volume VII. A large portion of this volume was published as an independent treatise in 1698. Volume VII. contains, in addition to the works of Picard, essays by Huyghens and astronomical letters from M. Auzout first published in 1665. An essay by M. Picard, now very difficult to obtain, written in 1671, to go with an atlas which appeared in folio form, is found in this volume. Other observations are described which were made for a folio volume printed at the Louvre and appearing in 1693. From a letter from M. Auzout to an Italian observer and instrument-maker contained in this volume, we learn the method then used for determining the diameter of the planets. There is also a description of a journey by M. Richer to Cayenne in the interests of astronomy and physics. Special journeys were made by de la Hire and others to different sections of France in order to secure accuracy in a proposed map. These were continued from 1672 to 1684. The accounts of these journeys are of considerable interest. The volume contains tables by which to find, on any day of the year, the time when the polar star passes the meridian, its horizontal declination and the height of the pole at any point on the earth's surface. There are accounts, too, of observations, physical and mathematical, made by the Jesuit fathers in India, Siam and China, and of the use made of the observations by the academy. Vol. VIII. is filled with the miscellaneous works of M. I. D. Cassini. A few of the suggestive titles are of interest: Origin and progress of astronomy, and its use in geography and navigation; elements of astronomy, verified by observations made

by M. Richer on the island of Cayenne; discovery of the celestial luminary which appeared in the zodiac; rules followed in Indian astronomy in the calculation of the movements of the sun and moon; reflections for a Chinese chronology; the island of Taprobane; hypotheses and tables of the satellites of Jupiter. In Volume IX. we have the works of de la Hire. They are mathematical in their nature, though they indicate acquaintance with the whole field of science. Volume X. treats of a wide range of subjects. Nearly four pages are occupied with titles alone. These essays indicate the direction scientific thought was taking and refer to matters of interest in physics, astronomy, anatomy and physiology. This volume was published in 1732 as a volume of extracts and papers from the records of the academy. As early as 1692 the academy had published a volume of its regular proceedings. A second volume appeared the next year. For the general reader Volume X. is undoubtedly the most interesting volume in the series. Many of the papers it contains had been given the public through the *Journal des Savans,* which was started at about the time the academy was organized. From the volumes in this series the works of Huyghens, Mariotte and Perrault are omitted, as their complete works had been published separately under the auspices of the academy. Volume XI. contains an analysis of new methods of resolving problems of all kinds and degrees to infinity. Though edited by M. Richer, it is the work of M. Delogny. The authenticity of this series of reports, with the history included in Volumes I. and II., is guaranteed by the signature of M. Fontenelle, perpetual secretary of the academy from 1699 to 1741. Fontenelle was born in 1657 and died in 1757.

Before speaking more definitely of the work done by the academy prior to its reorganization at the beginning of the eighteenth century, it should be noticed that in this academy we have the earliest example of cooperation in scientific study and of the endowment of research.

Colbert's plan was to bring men of scientific attainments together, and make it possible for them, at the cost of the king, to devote themselves entirely to work in their special departments. No better plan than that adopted in 1667 could at that time have been conceived. Funds were provided out of the royal treasury for experiment and costly journeys. Sir Isaac Newton was aided by this academy, which not only in this instance, but through its correspondence with other learned bodies, showed its hospitality for learning and its readiness to accept truth no matter from what source it might come. It has often been said that Newton needed a Paris Academy and a Laplace to make his theories popular, not only in France, but in all Europe. His "Fluxions" known as early 1675, were not published till after Descartes, in 1684, had given his "Calculus" to the world. These dis-

coveries were of immense value in scientific study. The academy early became a kind of clearing house for European scientific students. Through it its members could make their opinions known to the world. The language they used and their literary skill rendered their writings popular. It was a rule of the academy, adopted at its organization to read every important scientific work published and report and discuss its contributions to the subject which it treated. The discoveries which members of the academy made, the instruments they used in their studies, the improvements suggested in many of them, were freely communicated in letters to other learned societies. For example, a careful description of the micrometer, invented by Picard and Auzout, was sent by de la Hire to Mr. Oldenbourg, secretary of the Royal Society of Great Britain. Correspondence was had with the society formed by a company of men in one of the provinces who called themselves *Les curieux de la Nature,* as well as with the society, Del Cimento, which flourished at Florence under the patronage of Leopold de Medici.

In this way the scientific world was united in a common aim, the increase of knowledge, at a time when many of the nations were at war. In this way it was possible for every discovery in science, every theory advanced in book or essay, to be criticized and discussed by a body of men who certainly were not inferior in mental endowment or in attainment to any equal number in all Europe. It was natural, therefore, that a book published under the auspices of the academy should receive wide circulation and careful consideration. As the work of one of the members of the academy was to a certain extent regarded as the work of all, the academy was proud of such a book as "The History of Plants" prepared by MM. du Clos and Dupont, with the aid of several other academicians, and published in 1676. Its popularity may be inferred from the fact that a second edition was called for three years after its first appearance. There was, however, a danger into which, during the later part of the seventeenth century, the academy fell, of being too practical in its work. To gratify the king or his ministers it gave a great deal of its time to the study of subjects which looked to an increase of the revenues of the nation, rather than to an increase of scientific knowledge. For example, much time was occupied in the analysis of the mineral waters of France, in studying methods of improving shipbuilding, the sailing of ships, in studying the principles of architecture, of bridge building, and other subjects, which, though of value to the country, were not those in which members of the academy were supposed to be most deeply interested.

One is interested also in studying the history and characteristics of some of the men who became famous in connection with the academy. du Hamel, the first secretary, though he had been a teacher of philosophy as well as of geometry, was given his place because of his

facility in the use of the Latin language and his skill in reporting the opinions of others. He remained in office till 1699, when he was succeeded by Fontenelle. It was eminently fitting that he should write a history of the academy as he had known it. Couplet was the first treasurer and the keeper of the instruments used in experiments, an office in which he was followed by his son; Couplet had been a mechanical engineer. Early in 1667, Perrault prepared a room in a laboratory placed at his disposal for the study of physics. By careful experiment he fitted himself for the study of comparative anatomy and vegetable physiology. The motive to these studies was curiosity rather than the thought that the knowledge obtained would be of profit to any one. The problems deemed most important were those of astronomy and geometry. Hence for a long time astronomical studies received the greatest honor in the academy, and outside of it. It is, therefore, not strange that the men who devoted themselves to these studies should consider themselves superior to their fellows. They were zealous for their department and paid little attention to what was done in other departments than their own. For a full generation there was ill feeling between members of the academy caused chiefly by differences of opinion in reference to scientific subjects. Yet advance was made in other departments than those of astronomy and mathematics.

Du Clos and Bourdalin analysed certain salts and observed the changes constantly taking place in many bodies. Mineral bodies were carefully examined. Denis Dodort sought to determine the virtue of plants by chemical analysis. Vegetables he tested by fire and obtained what he and others called *caput mortuum*. The worthlessness of this method was pointed out by Mariotte in 1679 in his essay on vegetation. Many abortive efforts were made by the academy to obtain fresh water from the salt water of the ocean. Special attention was given to a study of the vacuum. de la Hire studied the chemistry of color, du Clos and Dodort the history of plants, the result of which, as has been said, published in 1676, brought great honor upon the academy. Dodort showed much skill in all his observations. His errors were only those of his time.

The plans of the authors of this volume embraced a complete history of plants. The great lack was knowledge of the physiology and chemistry of vegetables. All naturalists were what are now called amateurs. They gave attention to many subjects. Thus Freniele read a paper in 1660 on insects, pointing out in particular some changes observed in the caterpillar. Mariotte brought out a theory of vision which was strongly opposed as unscientific by Pacquet and Perrault. He wrote on hydrostatics also. Strenuous efforts were made, for a number of years, to measure the height of the pole at Paris. It was observed that the pendulum beat with differing degrees of rapidity at

the poles and the equator. Yet in spite of the jealousy of mathematicians and astronomers, every subject of scientific importance sooner or later was discussed in the academy.

Efforts were made by the king to bring into his academy the most eminent scientists of all countries. Thus Huyghens came from Holland at the founding of the academy. Jean Dominique Cassini, an Italian astronomer, came from Florence in 1669. Olais Roemer, of Denmark, came in 1674. He was the first to measure the velocity of light by observing the eclipse of the satellites of Jupiter. Nicolas Hortzoeker, of Düsseldorf, an optician, though residing in Paris for a time, preferred his independence under the elector Palatine to service in France under the king. Neither Tschirnhauser, nor the two Bernouillis, nor Sir Isaac Newton would expatriate themselves to become active members of the academy. They were content to be foreign associates and the academy honored itself by making them such.

A visit from the king in 1681 was a memorable occasion, especially for the astronomers, in whose work and instruments he was deeply interested. The visit brought larger and better equipment for the academy. Yet the king did not hesitate, at the suggestion of minister Louvais, who cared less for science and research than Colbert, to employ members of the academy for objects which had little reference to science. de la Hire was given tasks at surveying. Others were commanded to look after the fountains and waterfalls at Versailles. Perrault, Roemer and Blondel were ordered to discover the height to which a bomb could be sent and to trace accurately its path. The tendency of the time was toward the practical. It is not surprising, therefore, although the study of science was not wholly given up, that during the last quarter of the century the academy should lose much of its fame as a center of purely scientific research. The time had come for a change in its management, or for its reorganization. To that we must now give attention.

THE PROGRESS OF SCIENCE

THE CONVOCATION WEEK MEETINGS OF SCIENTIFIC SOCIETIES

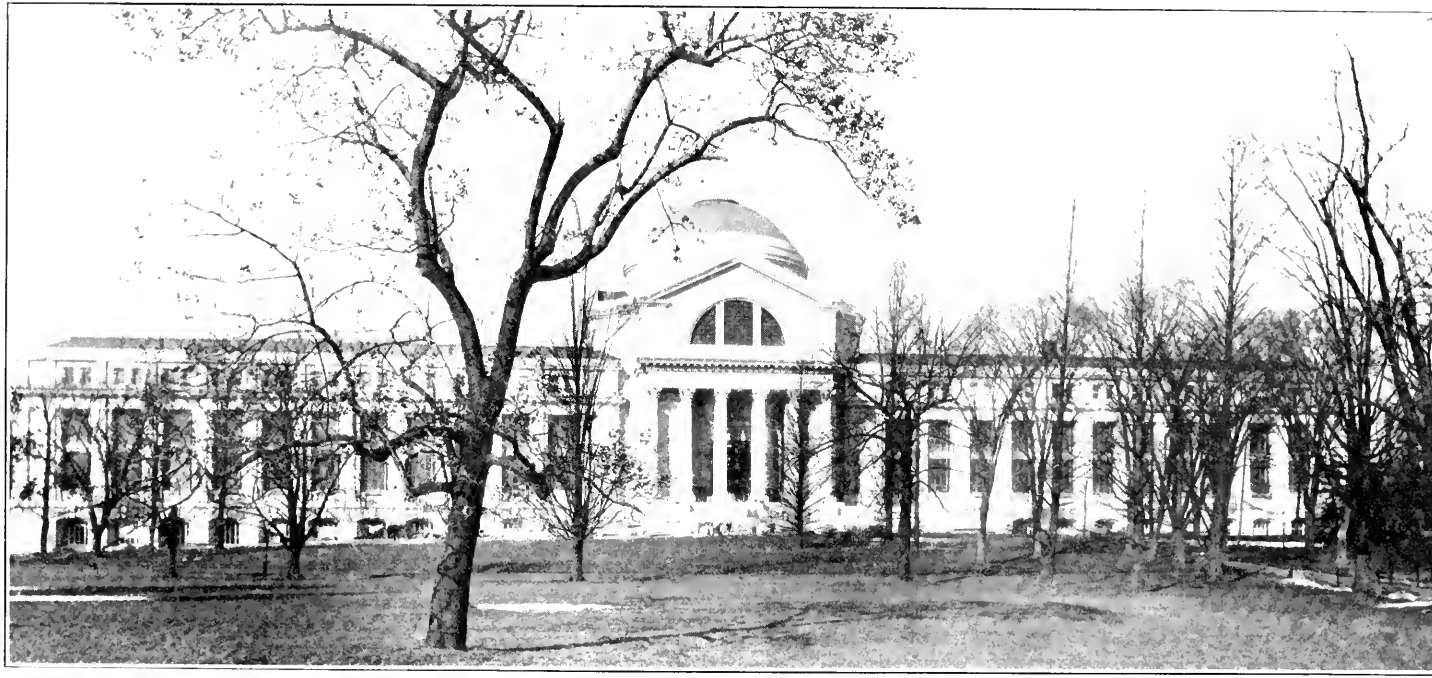
THE sixty-third meeting of the American Association for the Advencement of Science will be held in Washington from December 27 to 30. This is the tenth of the annual convocation week meetings, the first of which was in Washington in 1901–2. In consecutive years meetings have been held in St. Louis, Philadelphia, New Orleans, New York, Chicago, Baltimore, Boston and Minneapolis. Although the zoologists and anatomists meet at Princeton, there will be in session at Washington some thirty-nine - societies and sections with an attendance probably exceeding two thousand scientific men. The formal opening will be in the new National Museum on Wednesday, when President Taft will welcome the association, and the annual presidential address will be given by Professor A. A. Michelson, of the University of Chicago.

Since the first meeting of the American Association in 1848, great changes have taken place in the condition of science in this country, in which the association has been an important factor and to which it in turn has been compelled to adjust itself. Sixty years ago all the scientific men in the country could meet together in one room and take an intelligent interest in the same problems. There are now some ten thousand scientific men, scattered over a wide area, engaged in special problems, which in many cases are comprehensible only to other specialists in the same field.

It was not until 1875 that the association was divided into two sections—one for mathematics, physics and chemistry and one for the natural sciences. In 1882 nine sections were organized, each with a vice-president as its presiding officer. But provision was needed for still greater specialization, and at about the same time national societies began to be established for the different sciences. The American Chemical Society was organized in 1876, and the Geological Society of America and the American Mathematical Society in 1888, and there are now some thirty societies devoted to different departments of science.

These special societies have to a considerable extent taken over one of the principal functions of the American Association, namely, the presentation and discussion of scientific work. The association has adapted itself to these conditions by becoming a center of affiliation for the various societies, omitting the reading of technical papers before its sections when the affiliated society devoted to the same subject meets at the same time and place.

The second function of the American Association—the diffusion of science—it still performs, especially through its publications. It seems impossible to accomplish all that might be done at the meetings, for even when attractive programs of general interest are offered, it is difficult to obtain an audience, and the newspapers and other journals of the country give very inadequate accounts of the meetings. It seems that there might be large numbers of people interested in the general problems of science, who would like to attend the meetings if the advantages were brought properly to their attention. It is not intended that membership shall be confined to those engaged



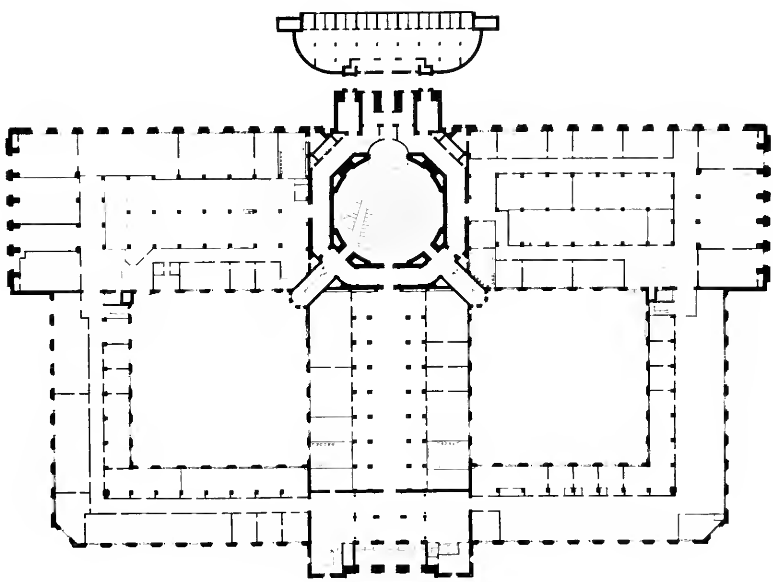
The National Museum from the Mall.

in scientific research, but rather to ally with the association all who are interested in scientific progress. Those who might like to become members of the association and attend the Washington meeting, should communicate with Dr. L. O. Howard, permanent secretary, Smithsonian Institution, Washington, D. C. The third object of the association is to unite those engaged in scientific research and those interested in science in an organization that will advance the interests of science and of scientific men. Fortunately these interests are coterminous with the interests of all the people, as the greater the advance of science the greater the benefit to all.

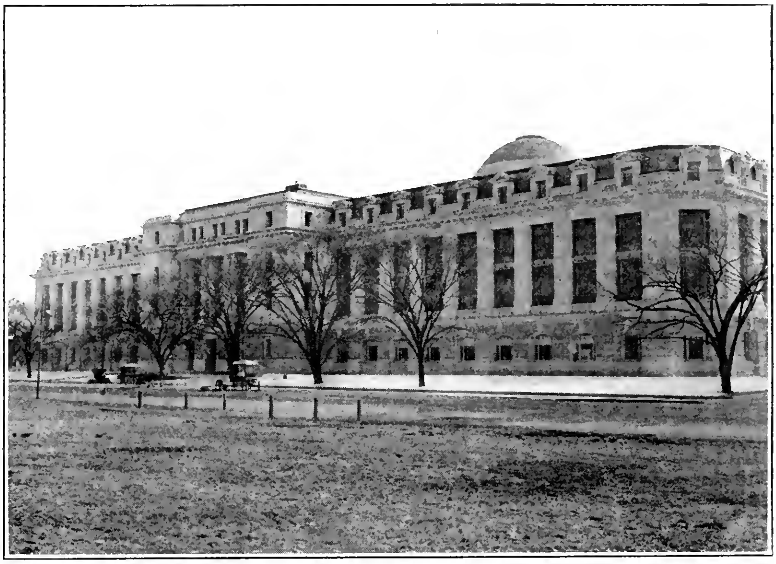
THE UNITED STATES NATIONAL MUSEUM

Washington is in many ways an admirable place for a large scientific meeting. There is much of interest in the city, both in its scientific establishments and in other directions. It is within reach of the chief centers of the country, and the climate is comparatively pleasant at this time of the year. But there are no places for the meetings so satisfactory as are offered by our larger universities. Within the last year there has, however, been a great advance in this direction by the completion of the new building of the United States National Museum. It possesses one good-sized lecture room in which the opening exercises and public lectures may be held, and the collections are a great attraction.

When the Smithsonian Institution was organized in 1846 congress entrusted to it the care of the national collections, and later undertook to provide for the maintenance of the museum and of the library. An adequate building for the National Library was built some years ago, and the new building for the National Museum has this year been completed, and the collections have been installed. The museum building covers a greater area than any other government structure in Washington, except the Capitol, and it is satisfactory that two of the most beautiful and well-arranged buildings



Ground Plan of the National Museum.



The National Museum from the Street.

in the city should be devoted to a library and to a museum. The general aspect of the museum and the ground plan are shown in the accompanying illustrations. The new building is placed on the Mall, the development of which still remains in large measure for the future, in front of the Smithsonian building, which it faces. It is a massive structure, four stories in height, with a frontage of 561 feet, a depth of 365 feet and a dome rising 162 feet above the ground level. The exterior of the building is not greatly ornamented, but its massive white granite and the lines and proportions give a pleasing effect.

The lower floor, called the basement, although it is raised several feet above the adjoining street, contains laboratories, workshops, storerooms and offices, used largely for the research work of the scientific staff. It also unfortunately contains a heating plant and ventilating system which pumps dust into the collections. The main floor presents a continuous floor space, the middle part of each wing being carried up to the second story. Three exceptionally large halls are thus formed, well adapted to the exhibition of the collections. The second story has less floor space, but ample galleries; the third story is reserved for laboratories and the storage of the collections intended for scientific research.

JOSEPH DALTON HOOKER

Sir Joseph Hooker is now dead at the age of ninety-five years. Only Wallace, aged ninety years, and Lister, aged eighty-five years, remain of the company of great men who were the contemporaries of Darwin. Since the birth of Roger Bacon, eight centuries ago, to the Victorian era, England has produced a succession of leading scientific men. We may hope that the hereditary genius of the race is not exhausted and that some part of it has been bequeathed to us in this country. Indeed Hooker himself is evidence of the persistence of genius, for his father was a botanist of equal eminence.

William Jackson Hooker, born in 1785, had independent means, which in

Sir Joseph Dalton Hooker-

England have so often led to a scientific career. He made important expeditions, devoted himself to the formation of a herbarium, and edited and published works contributing greatly to the advancement of botany. In 1820 he became professor of botany at Glasgow, and in 1841 director of the Royal Botanical Garden at Kew. His son, Joseph Dalton Hooker, was born on June 30, 1817, and immediately after taking the M.D. at Glasgow accompanied as assistant surgeon Sir James Ross's Antarctic expedition, the botanical results of which he subsequently published. Four years in India produced contributions of even greater importance, and later journeys were undertaken to many regions, including Palestine, Morocco and the United States. In 1855 he became assistant director of the Kew Gardens and succeeded his father as director in 1865.

Hooker's relations with Darwin were intimate, and he is perhaps best known to those who are not botanists for his support of the theory of evolution by natural selection, beginning with his presidential address before the British Association in 1868. But his botanical contributions are immense in range and importance. It is only necessary to mention here the "Flora of the British Isles," "The Flora of British India" and the great "Genera Plantarum."

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. George Davidson, eminent for his contributions to geodesy, geography and astronomy, emeritus professor in the University of California; of Surgeon General Walter Wyman, of the U. S. Public Health and Marine Hospital Service; of Sir Samuel Wilkes, London physician, author of works on pathological anatomy, and of Dr. Max Jaffe, professor of pharmacology at the University of Königsberg.

The Nobel prizes have been awarded in the sciences to Mme. Marie Curie, of the University of Paris, in chemistry; to Professor Wilhelm Wien, of the University of Würzburg, in physics, and to Professor Allvar Gullstrand, of the University of Upsala, in medicine.

The Symons gold medal of the Royal Meteorological Society has been awarded to Professor Cleveland Abbe, of the United States Weather Bureau.

The following awards have been made by the president and council of the Royal Society: a Royal medal to Professor George Chrystal, Edinburgh, whose death has meanwhile occurred, for his researches in mathematics and physics, especially his recent work on seiches and free oscillations in the Scottish lakes; a Royal medal to Dr. W. M. Bayliss, F.R.S., for his researches in physiology; the Copley medal to Sir George H. Darwin, K.C.B., F.R.S., for his scientific researches, especially in the domain of astronomical evolution; the Davy medal to Professor Henry E. Armstrong, F.R.S., for his contributions to chemical science; the Hughes medal to Mr. C. T. R. Wilson, F.R.S., for his investigations on the formation of cloud and their application to the study of electrical ions.

THE POPULAR SCIENCE MONTHLY.

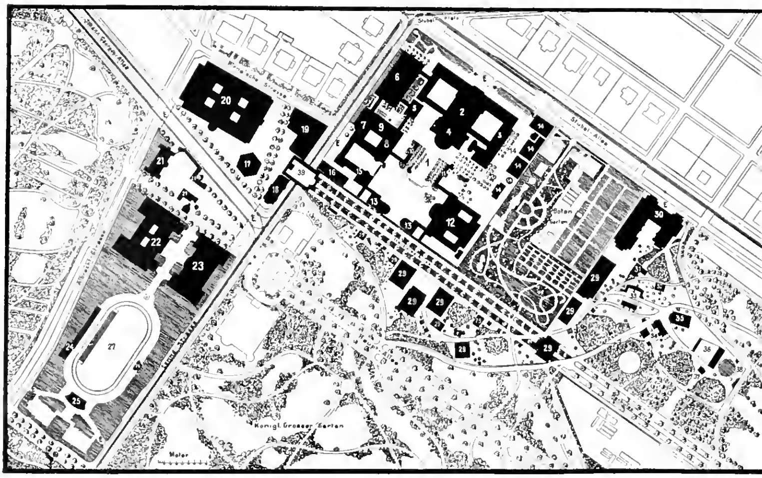
FEBRUARY, 1912

THE INTERNATIONAL HYGIENE EXHIBITION AT DRESDEN

By Dr. HENRY G. BEYER

MEDICAL DIRECTOR, U. S. NAVY, U. S. DELEGATE TO THE EXPOSITION

THE "Internationale Hygiene Ausstellung, Dresden, 1911," has by this time closed its doors and passed into history. It was one of those rare and remarkable creations of the human mind that will absolutely refuse to die. The exposition itself was only the opening scene in a performance which had its beginning in the month of May and ended with a climax in the month of October, when the curtain dropped. Its real work, though impressive and monumental from the start, has only just begun. Little folks and little minds may criticize the little imperfections about it from a distance. Those who are in the habit of looking for principles in things with broad and generous minds, having taken the trouble to visit and study the exposition more conscientiously, were overwhelmed with its grandeur, its beauty and the nobility of the motives underlying the undertaking. Fortunate indeed are those who were allowed to witness the great event, still more fortunate those who may count themselves active participants in it. For, nothing, no event in history, could be cited as showing the working of the human mind in the Germanic race of man, as illustrating it in all its splendid attributes and as placing it in a clearer light, to better advantage, than did this magnificent hygienic exposition. No other human endeavor could be cited as showing the ultimate motive power in the accumulation of personal wealth to be, in reality, that of aquiring the ability and power of giving to others and of, thus, contributing to the happiness of others, than did this exposition. As an organized endeavor to prevent sickness and prolong human life, to project the living laws of health and happiness into the minds, the hearts and the very homes of people, it certainly surpassed anything of the kind in the whole history of hygiene and sanitation.



GROUND PLAN OF THE EXPOSITION.

There is not a single visitor who does not regret the shortness of the existence of this great exposition; who did not feel his interest in it increasing daily, while in attendance; who would not welcome an opportunity of returning to it for more instruction and inspiration; who was not moved to wish that every living man and woman might receive the benefits this exposition was intended to convey and to disseminate.

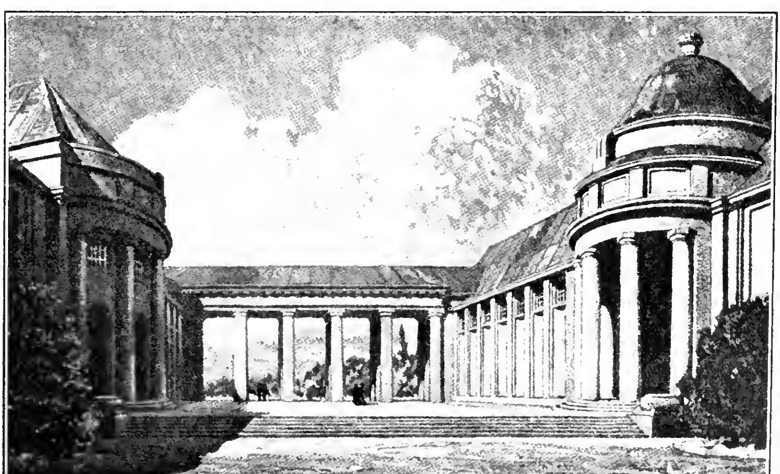
All expositions are schools of learning of the most practical sort. International expositions are the universities in which the different nations teach each other. The exhibits, carefully selected and arranged in groups, represent the achievements of many years, the results of many years of study and labor, in a predigested form and ready to enter the understanding without requiring any effort on the part of the observer, except that he be in a receptive mood. There was a time when the attributes of usefulness on the part of the high arts and sciences were regarded as detracting from their value; when the beauty of an object was thought to end where its usefulness began; when sciences, we were told, had a right to exist for their own sake and regardless of their usefulness to mankind. Human physiology itself, during its juvenile development in recent years, had become so precociously independent as to barely recognize its ancient relationship to mother Medicine. What a remarkable change of front in this general attitude has been made in a few years, was perhaps never better shown nor more efficiently demonstrated than in the "Internationale Hygiene Exposition, Dresden, 1911," where one great, intelligent, strong mind succeeded in gently pressing the fruits of every known art, science and industry into the service of humanity. Disciplined, orderly cooperation toward one common and useful end and purpose was never and nowhere shown to better advantage than in the work of organizing, creating and

conducting to a successful termination this truly great exposition. By no means the least that can be said of it is that it proved to be a financial as well as a scientific and philanthropic success.

A General View of the Exposition Grounds

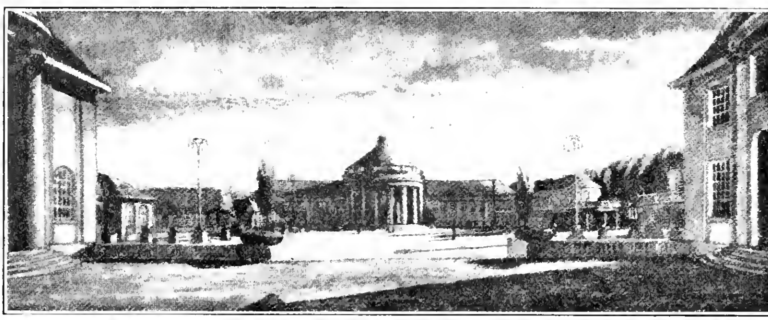
The exposition grounds cover in all an area of 320,000 square meters, of which 70,000 square meters are occupied by buildings, 72 in all, large and small. This immense area was contributed partly by the "Grosse Garten," partly by the Royal Botanical Garden, the park of Price John George and the Dresden Commons. The Lenné-Strasse, dividing this area, was bridged over. One of the first serious difficulties in planning with which the Dresden architects were confronted was to so distribute their buildings that the large fine old linden trees in these various parks should not be damaged. This difficulty they succeeded in overcoming to perfection. They distributed the various buildings in such a manner as to make the trees serve as a rich green background for them, thus, at the same time, avoiding rigid geometrical lines and producing, instead, a most picturesque effect.

The main entrance to the grounds consists of three rows of large and imposing columns, covered in above. Passing through these columns, and to the right of the main entrance we find the administration building which houses the various offices of the director, assistant directors, the post offices, the fire department and the sanitary and red-cross companies, all excellently and most efficiently organized: to the left stands a very large structure containing the assembly hall, intended for the meetings for the large number of congresses that met in Dresden during the summer, the various exposition halls for school hygiene and the care of children, exhibition rooms for dental hygiene, tropical hygiene and chemical industries, for infectious and venereal diseases.



Main Entrance from within.

From the enclosed oblong square, the visitor overlooks a larger open space and notices in the distance the imposing structure devoted to popular hygiene which is marked above the entrance in large and imposing letters, "Der Mensch." This imposing structure has a prominent, semicircular entrance, divided by a series of large columns, 11 meters high, surmounted by a cupola and leading into a spacious vestibule, on either side of which are wardrobes, and, finally, into a magnificent hall, with a stage or podium at its furthest end for giving seating capacity to the officers conducting various meetings, with their guests of honor. Against the background of this stage there is visible a large statue with the inscription "No Wealth is equal to thee, O Health!" This entire building is devoted to popular hygiene. Passing down the wide steps of the first open square, we find ourselves entering a large open enclosure in the grounds. This is the so-called "Festplatz." On the sides of this Festplatz are various small stores, a



MAIN COURT OF THE EXHIBITION.

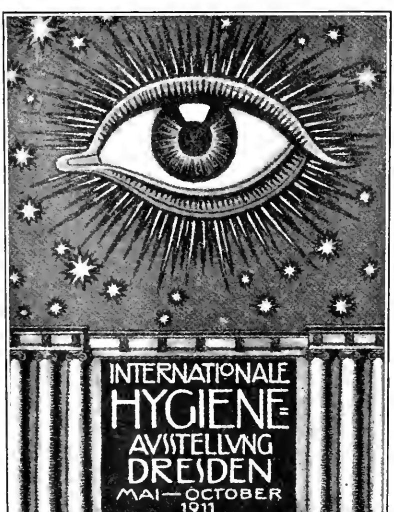
music pavilion, garden restaurant, to the right a wine restaurant with a terrace above and the recently erected pavilion of Great Britain. Farther to the left and overlooking the garden restaurant there is the permanent exhibition building of Dresden, artistically embedded among the new buildings. On the left, also, and against the botanical garden we find the recreation park. This park is occupied by a very original Bavarian restaurant, a hippodrome, a place for dancing, an academic *Beer-kneipe*, Japanese and Indian tea-houses. This recreation park proved a great necessity in that it accommodated the overflow of sightseers and gave them a chance to rest and refresh themselves, lending at the same time variety to scenery and interest to sightseers, without interfering with the intended serious character of the exposition.

The city exposition palace, Steinpalast, forms the center of the exposition; this palace had to undergo extensive interior changes to accommodate the historical and ethnological sections, some of the most remarkable features of the whole exposition. While exhibiting most effectually the contrast between past and present conditions as regards hygiene, it also showed and illustrated what we hear so often without

attaching any profound meaning to it, namely, that there is nothing new under the sun, and what we call new, in reality, embodies an old and identical idea in a new garb.

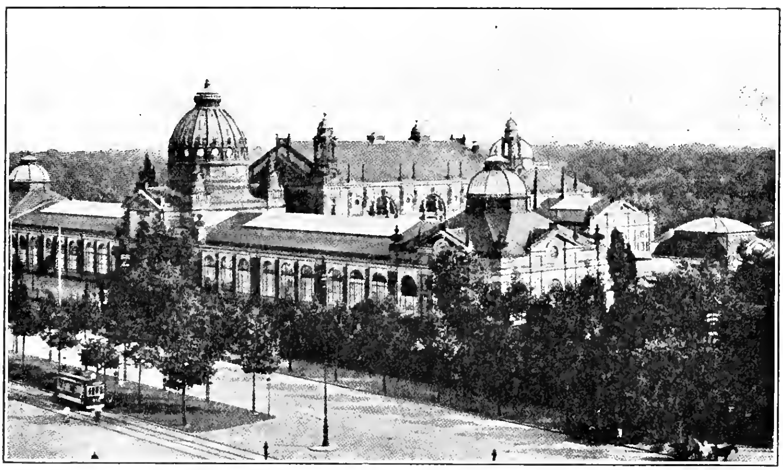
DR. K. A. LENGNER,
President of the Exposition.

Connected with the Steinpalast by large halls is the "Hall for Chemical Industry" and scientific instruments. To the right of the large "Festplatz" and between it and the "Grosse Garten" and amidst a long row of fine large linden trees, there runs along an avenue, 40 meters wide, along one of the sides of which foreign nations have erected their pavilions. China has erected a pavilion in the form of a pagoda. Austria has built a large-sized rectangular structure with a massive roof, high walls, large windows and wide imposing entrances. Russia has erected a building after designs made by a Russian architect and resembling in style some of the buildings seen in the Kremelin. Japan, likewise, has contributed a rectangular structure, after a national design, simple but most effective in displaying the exhibits. Switzerland, has put up a building characteristic of the Bervese Netherlands, Spain, Italy, France, Hungary and Amsterdam all have erected pavilions in style of architecture exhibiting the national characteristics in their design. This "rue des nations" shows off well at night when illuminated. Passing out of the "rue des nations" and around the end of the botanical garden, we come in sight of the several large halls, housing life-saving devices, means for the care of the sick and injured, traffic on land and sea, appliances used in the care of prisoners and the insane, army, navy and colonial hygiene. A sylvan restaurant stands at all hours ready to administer to the physical need of the visitor.



A number of smaller buildings, devoted to various purposes, such as the care of the crippled, the housing of the poor, sylvan burial of the dead, the rearing of various species of rabbits for food purposes, a model stable for cows and clean milk production, form the outskirts of this part of the exhibition grounds.

Passing now over the bridge across the Lenné-Strasse which separates the two main divisions of the exhibition grounds, we may either climb the few steps that lead up to the bridge or simply step on the inclined surface of a sidewalk, in constant motion, carrying passengers up at the expense of two and one half cents. The bridge leads the visitor over into the second great division of the grounds. Here we find, on the right, the large hall for occupational hygiene, on the left the power-house; facing the visitor is the gigantic hall marked "Settlement and Habitation," one of the richest, so far as contents are concerned, of the whole exhibition. Passing the music stand and turning to the left, we have, on the left, an Abyssinian village; on the right several small and large restaurants and enter a large open space having on one side the large hall devoted to the hygiene of clothing and the general care of the body, on the other the hall exhibiting nutrition, dietetics and food stuffs, while facing us, in the distance, there is the large oval for sports with its stadium, music stand, grandstand, restaurant and sport laboratory, as well as the immense swimming tank called "Undosa." In this swimming tank, artificial waves about three feet high are produced by mechanical means and the bather gets the benefit of an open air bathing resort nearer at home.



Main Building.

The sport laboratory is fitted out with all sorts of scientific instruments and apparatuses to investigate scientifically the effects of physical exercise on the human body, especially on heart and lungs. A gymna-

sium shows the usual development instruments well stocked with material. The great oval is for out-of-door meets and is almost daily in use.

In thus decentralizing the interesting points of the exhibition, the administration was parting company with the principles of housing everything under one roof and thus made a new and very attractive innovation. It avoided overcrowding of the visitors and divided them by a variety of interests located in different halls; it reduced the danger of a large fire, hoping, in case there should be one, to limit it to one or a part of one building by a system of hydrants most generously distributed through the grounds. Through this division of subjects among a large number of buildings it was possible for the visitor to pursue his studies on the subject he was interested in especially, without being disturbed and crowded out by visitors interested in other pursuits.

The Exposition Buildings

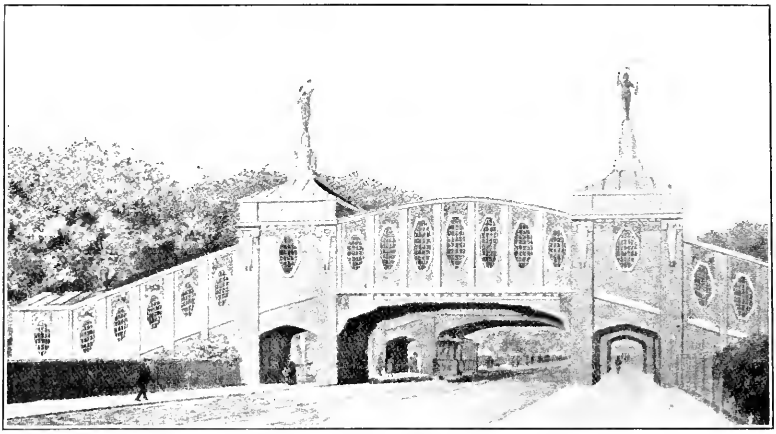
One of the most noteworthy features of the exposition was the architectural beauty of the buildings, including their interior decorations. While the designs of the various buildings differed from each other individually, their structural execution showed that they belonged to the same genus, while all were artistically adapted to the more practical purposes which they were intended to serve. Made principally of wood, all exposed surfaces were provided with a fireproof, coarse-grained covering. Gay, but superfluous, bunting, likely to catch fire and calculated to detract the visitor's eye from the main objects of the exposition, was carefully avoided, while a fine sense of artistic finish, calculated to invite the visitor to concentrate his attentions on the chief objects of the exposition, was everywhere apparent. The quiet, serious character of the buildings, their generous dimensions, large door-ways, wide passage-ways, an abundant provision of light and air, were features without attracting special attention to themselves, that were nevertheless in the most perfect harmony with the serious purposes and the hygienic characters of the exhibition and aided materially in sustaining instead of fatiguing the attention of the visitors.

The Exposition

It could never have been our purpose to attempt giving a full description of this exhibition. Such an undertaking would require a whole corps of editors and end in the publication of a long series of illustrated books. The intention here is to give only a very brief review of a *few* chapters in the greatest living handbook of hygiene ever put together and for which the exposition stood from the beginning and to which high purpose, in reality, it remained true to the end.

Steinpalast

Historical Division.—How deep, wide and far-reaching were the conceptions dominating the minds of those that were called upon to



The Bridge over the Street.

plan and organize the exposition, was in no department of the exhibition better shown than in the historical division. There was to be no mere comparison between what hygiene is now and that which it represented fifty years ago, but the problem before the organizers was to trace the whole history of hygiene from the remotest beginnings to the present time and to illustrate this gradual evolution by pictures, models and objects, actually dating from those times.

Among the prehistoric Kelto-germanic exhibits could be seen food-stuffs, etc., dating from the stone age. A wall picture from a slightly later period displayed the remarkable fact that the wasp-like waist so much admired on the part of the female sex to-day had been already the ambition of the prehistoric woman. To ward off disease by the wearing of amuletes was already then in vogue.

Prehistoric Babylon shows that, in these remote times, the most detailed precautions were already taken for keeping all sorts of insects off from food articles, especially during the serving of them. The hygienic tendencies of old Babylon are shown in the technique employed in the construction of their wells, canalizations, bathing establishments, latrines and burial systems. The practise of isolating cases of infectious disease, of cleaning food-stuffs before they were eaten and of setting aside a fixed number of days for rest and recreation, was already then commonly observed in Mesopotamia.

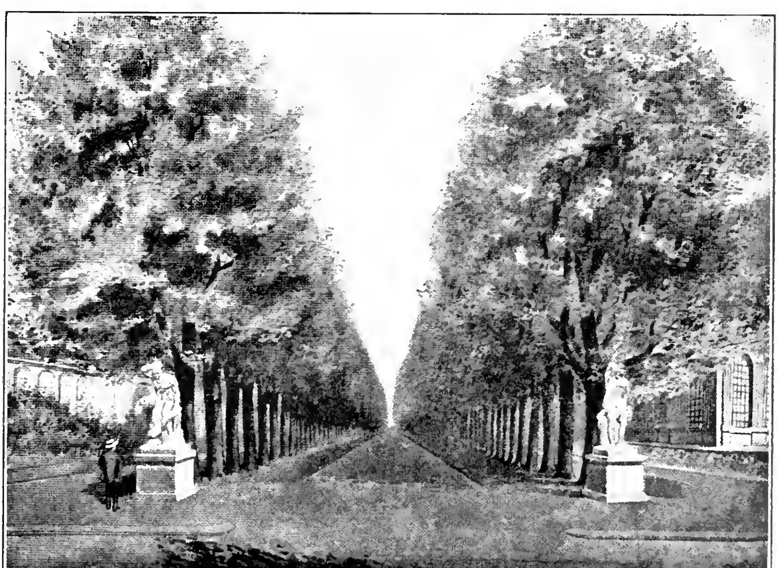
The significance of old *Jewish hygiene* is abundantly shown, in the directions on the treatment of articles of food, the regulation for sexual intercourse, the treatment of excrements, burial rites, instituting the regular sabbath which has conquered the world, the priestly inspection of lepers, preserved in old and time-honored rolls of the Tora and further illustrated by sketches, photographs and models.

In prehistoric *Egypt,* the manifest tendency of preserving the human body after death for a future life in an unchanged form is

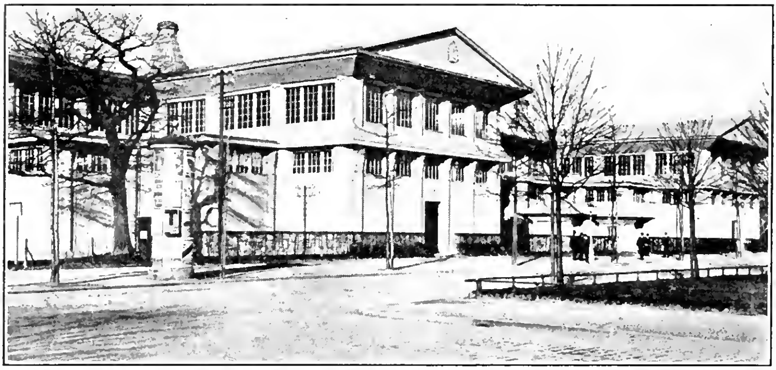
hygienically considered the most interesting. That the sun-dried soil of Egypt contributed largely to the results obtained is shown when original mummies are compared with the results obtained by artificial drying of animal bodies. To what an alarming extent organized disease-producers had been at work thousands of years ago, on the Nile, is abundantly shown in a large collection of preparations of Egyptian origin in glass bottles.

The statues of the Venus of Praxiteles and of the Doryphoros of Polyklet serve to show how much attention was paid already in those early times by the Greeks to the care and systematic development of the human body from early childhood throughout adult life. That the goddess Hygeia stood in great esteem in ancient Greece is shown in citations from Grecian poets. Models of the recent excavations of the town of Salona in Dalmatia show us a typical Roman provincial town with its splendid streets, water-supply and sewer systems and bathing establishments; a third model, also, shows one of the thermal establishments of Imperial Rome, that of Caracalla. Storerooms for provisions, grain mills and kitchen hearths of Greco-Roman culture are shown in the form of models. Wall pictures complete the illustrations of the dietary customs of ancient Rome and Greece. Numerous models of Etruskan and Sardinian types of houses showing the construction of latrines, the methods of lighting and heating, their bathing establishment, treats exhaustively of the home life of these times.

A special room is devoted to showing how great and thorough were the hygienic precautions promulgated in both Greece and Italy. These



Avenue of the Nations.



Hall for Army, Navy and Colonial Hygiene.

ancient framers of the laws already knew the great value to the state of strong and healthy people as shown by the laws they promulgated. Food adulterations also received their due share of attention. But the most significant hygienic characteristic of ancient Rome and Greece centers undoubtedly in the methods of street construction, water supply systems and sewerage systems.

Another special room is devoted to showing the efforts of the physicians of those ancient times as being not alone those of restoring the sick to health, but also those of preventing the well from becoming sick. A plan of the sanatorium in Kos shows its sanitary situation on the south side of a hill covered with trees. Mothers were made to nurse their own children or substitute a wet nurse; the bottle came into consideration only as a feeding instrument of children during the second year of their lives.

The last room of classical antiquity is devoted to burial customs. It is here shown that cremation was not the exclusive method of disposal of the dead in classical antiquity.

We shall have to pass over the different epochs that mark the progress of hygiene during the middle ages, which was shown and interestingly emphasized by a great variety of exhibits, collected from all parts of the world and contributed at great expense, distributed through 22 rooms, both large and small, and in which that gradual but steady progress was shown by graphic, plastic and pictorial exhibits from the time when physicians diagnosed disease by simply looking at the urine-bottle of their patients, up to the period when hygiene began to be taken more seriously and entered into the dignified domain of an experimental science.

We must, likewise, pass over the ethnological portions of the exhibition, although most interesting and highly instructive in showing the customs and habits of the different races peopling our globe and their common desire for a long, happy and healthy life.

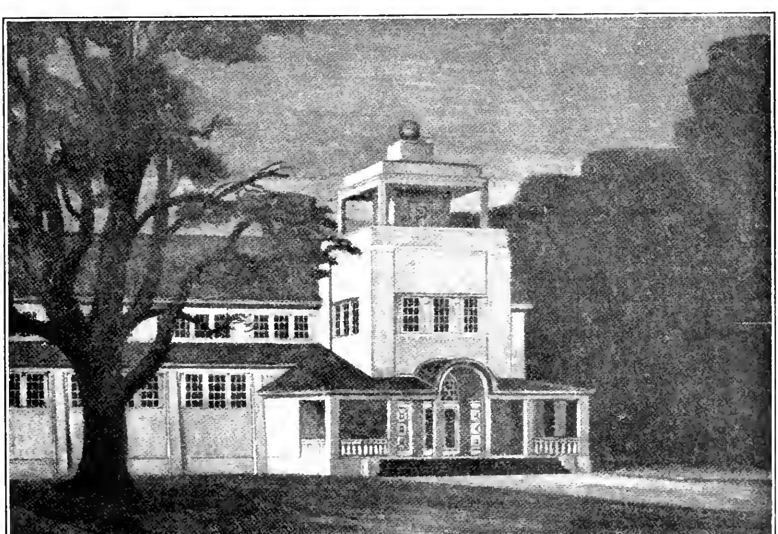
In leaving the historical and ethnological groups of the exhibition,

one can scarcely turn aside an ever-increasing impression of the existence of a great variety of distinct and widely differing species of the genus *homo*. Even if a common origin for all should finally be accepted, it will have to be admitted that the genus man has shared in the tendency of all life in general, namely, that of producing varieties, differing almost as widely from each other in their habits and productions as do the various organs in a single individual living animal organism in their functions. The study of the comparative physiology and psychology of races (ethnology), therefore, teaches us that their respective manners, customs and achievements differ in accordance with their hereditary composition and will continue to do so to the end of time.

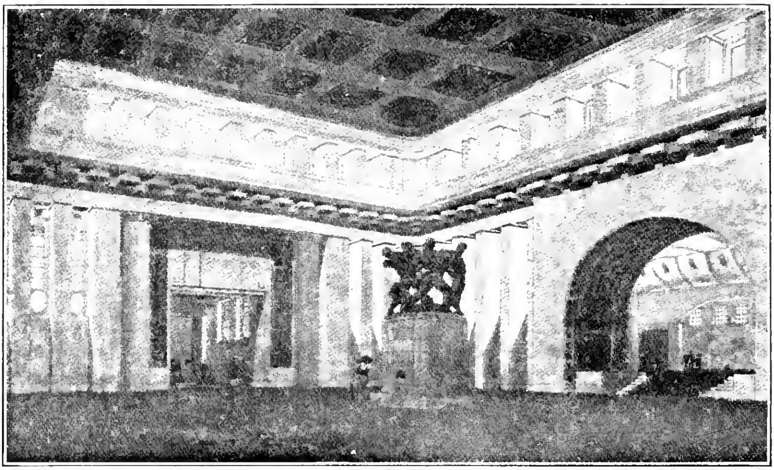
About 450 individuals and firms had sent contributions to the historical group of the exhibition alone.

The German Workingmen's Insurance

The handsomely bound catalogue by Dr. Klein for the special exhibition, intended to inform the visitor of the work accomplished by the German workingmen's insurance, covering 107 pages, and filled with but the briefest mention of the objects exhibited, will give an idea of the wealth of the material found in Hall 10, presided over by Dr. jur. et med. Kaufmann and Geh. Rat. Weger. The workingmen's insurance, instituted in 1885 by Emperor Wilhelm I., pursues the object of protecting the workingmen against the unavoidable dangers of their calling. Every working man and woman within the boundaries of Imperial Germany is, regardless of nationality, legally insured against disease, accident, invalidity and old age. The sums of money thus contributed to the various workingmen's societies reach the limits of the incompre-



Hall for the Hygiene of Transportation.



Central Room of the Building for Settlement and Habitation.

hensible. To mention only the sums contributed in this way during the year 1909:

	Marks
Sickness insurance	342,200,000
Accident insurance	162,266,000
Invalidity insurance	189,029,000
Total	693,495,000 or
Daily	1,900,000

The comprehensiveness of the machinery of the workingmen's insurance is beautifully illustrated in the picture of an oak and its effect on the whole body of workingmen is intended to be shown by a figure representing a workingman, designed by Professor Hosaeus, Berlin.

Race Hygiene. Director Dr. von Gruber, Munich

Race hygiene has for the first time found a place in hygienic exhibitions. It had for its object the calling of the general attention of the public to the immense importance of heredity upon the prosperity and the degeneracy of the race, upon the inherited constitution which, when strong, bids defiance to unfavorable conditions, when weak, succumbs in spite of the most careful nursing. The public at large must learn to appreciate the necessity for exercising a reasonable amount of care in the selection of a life partner.

With the aid of 200 tables, charts and colored natural objects, the laws of heredity were demonstrated and it was shown how, through the continuity of germ plasm, in plants and animals, different characteristics are transmitted from one generation to another. The different kinds of variability, as fluctuation and mutation, are made clear. The laws established by Mendel, together with the results of the latest experi-

ments on the transmission through heredity of acquired characters and of diseases, have received due regard.

Attention is also devoted to the question as to whether the nations of the highest culture are increasingly degenerating. The dying out of certain distinguished families and the decrease in number of those fit for military service is taken into account. The special toxic influence of alcohol and syphilis on germ plasm as well as the influence on the race of inbreeding and race-crossing is considered. Finally, the significance of the intentional prevention of conception, or the Neomalthusianismus on the race problem is shown. For further details we must refer to the very comprehensive guide, published by Max v. Gruber and Ernst Rudin, for use in this group of exhibits. This book possesses a value of its own, beyond its mere usefulness as a guide through the momentous group of exhibits.

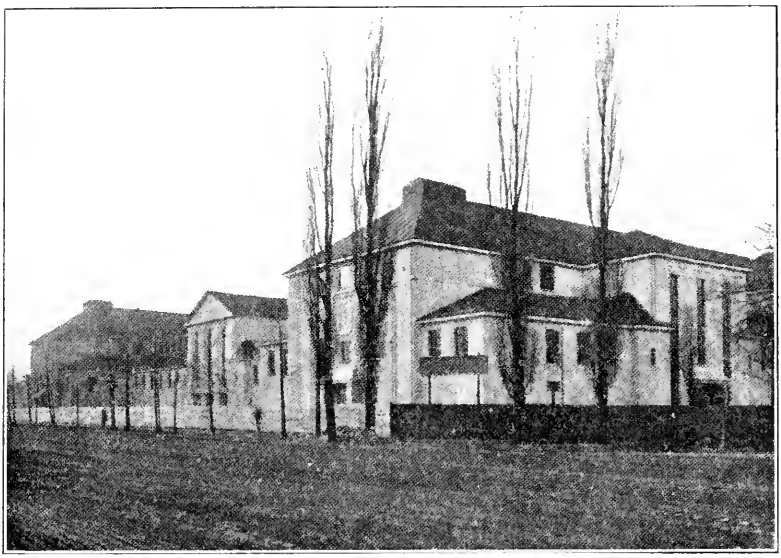
Sport Division

The organization of the sport division of the International Hygiene Exposition, Dresden, 1911, marks an important epoch in the history of bodily exercises. A rigid classification of sports according to physiological principles has, for the first time, been rigidly carried out. The scientific committee is represented by such men as Professor Zuntz, Berlin, Professor Schmidt, Bonn, E. von Schenckendorff, Görlitz, and many other eminent and learned men. The so-called German Sport Committee stands under the protectorate of the German Committee of Olympic Games: Eæz. von Podbielski, U. von Oertzen and Dr. Martin, presidents, and with the chairmen and secretaries of the large German societies as members. The real working committee is the organization committee under the presidency of Dr. Becker. The special divisions under this organization committee are: academies, fishing, automobile and motor sports, aviation, boxing, ice and snow sports, fencing, women-sports, golf, hockey, chase and shooting, bowling, lawn-tennis, military wheel-field-riding sports, roller skating, rowing, swimming, sailing,

Ideal Figures of Antiquity.

gymnastics and gymnastic games, wandering and mountain climbing. The members of the individual groups were selected from and by the associations distributed over the whole country. From the above an idea may be gained of the comprehensiveness of the organization. The sport exposition was divided into the following subdivisions:

1. Special gymnastic exhibitions by the different unions.
2. Scientific division.
3. Industrial sport division.
4. Sport places and sport plants.
5. Sport laboratory and library.



Hall for Nutrition, Dietetics and Foodstuffs.

6. Tournaments.

In the sport laboratory were made:

1. Anthropometric and ergographic investigations.
2. Electrocardiographic examinations.
3. Röntgen-ray observations.
4. Examinations on the chemistry and mechanics of respiration.
5. Microscopic and chemico-physiological investigations.

A dark room and a library completed the laboratory. A large number of university men had voluntarily contributed their services to the success of the work. The object of this laboratory was to furnish material for the laying of a foundation for a scientific sport-physiology and sport-hygiene. From results already obtained in this laboratory, some of which I had an opportunity of examining, I am convinced of the fact that a beginning has at last been made for the scientific elaboration of the proper principles upon which alone the different forms of

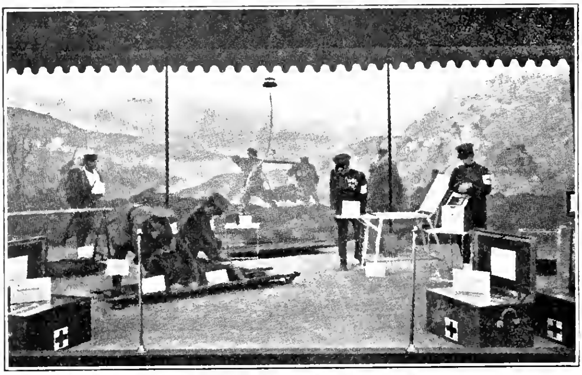
exercise may be made useful and beneficial, instead of hurtful and dangerous as most of them are now. German sport is intended to remain an amateur sport; it is not to be a wild record breaking mania and struggle for money premiums, to satisfy the overwrought ambitious few; it is not to satisfy the curious wishing to see celebrated champions. The time-honored title of sportsman is to be denied to those who witness a tournament simply because they want to bet on the results. Professionals who are in it for what they can get out of it are not to be called sportsmen; the German sportsman is to remain a gentleman, active without being greedy for gain. The pleasure in tournaments, a national characteristic, is not to be discouraged, but it is not to be regarded as the highest aim of sport. A sentiment for out-of-door sport is to reach the entire nation; it is to bring the individual citizen from his office and workshop out under the influence of God's sunlit nature, to enable him to stretch his limbs and to fill his lungs with oxygen and his mind with the beauties of nature.

Manly virtue, endurance and resistance are to be placed above calcified arteries, enlargements of hearts and collapse. To this program the sport division of the exposition has remained true throughout.

The Significance of the Hall, Marked in Large Golden Letters, "DER MENSCH" at the Internationale Hygiene-Ausstellung

The conventional attitude in fashionable society of displaying an unconscious ignorance with reference to everything concerning the structure and functions of the different organs of the human body is gradually losing the character of its traditional respectability. The forces at present operative in shaping the destinies of human races have rendered such a display of lack of knowledge culpable to a degree and its further cultivation a crime. The most formidable governing power in any free and enlightened country being admittedly based upon a sound public opinion, itself a function of the degree of the general health of its citizens, it clearly becomes the duty of every individual to contribute to this constitutional asset of his commonwealth, in proportion to his personal intelligence and educational standing, as the most valued tax that can be levied on his citizenship, for it seems pretty well acknowledged that the future will belong to the nation possessing the greatest number of strong, healthy and physically as well as mentally resistant individuals.

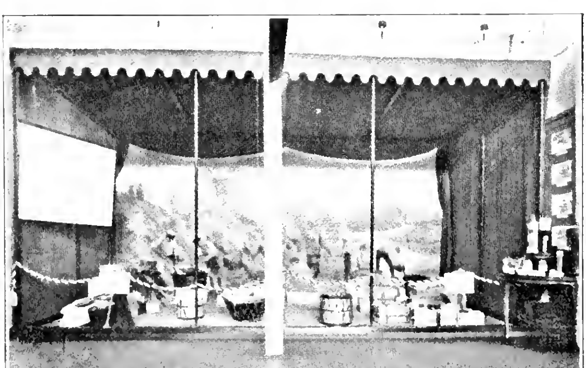
As a contribution to the methodology of disseminating such knowledge among the people in the most effectual manner, the hall of popular hygiene at Dresden stands preeminent in recent times. Structure and functions of the human body were never before presented in a more easily assimilable form. The conditions necessary for the preservation of health and for the prevention of disease were never before set forth in so easily intelligible a manner. Neither expense nor pains had been



FIELD HOSPITAL.

spared to render clear to the understanding the mysteries of health and disease. All the available arts and sciences had been pressed into service of this great object. The systematic representation of the subject was pursued with great consequence. An introductory lecture was given in the great hall every morning. A culture of living protozoa was projected on the screen in an adjoining dark room, their life histories explained. In another dark room, the production of antibodies in the blood, excited by the action of bacteria, was shown on the screen. Then, the life cycle of the silk worm and the preparation of silk was similarly shown on the screen. Over one hundred microscopes, all in the most perfect working order, and under a splendid system of illumination, served to demonstrate monocellular organisms, mitotic cell-division, fertilization and embryonic development as well as the adult cellular structure of every organ in the human body.

The gradual development from a single cell of some of the lower animals as well as intra-uterine development of the human embryo was beautifully shown by a series of embryos rendered transparent by the method of Spalteholz. A splendid series of wax and plaster models in



FIELD KITCHEN.

glass cases, greatly assisted by attached mechanical devices, helped the understanding of their structure and function.

The adult human body was, in its entirety and in parts, shown in the natural state, in the form of models, paintings, lumières and drawings, all displayed in the most artistic form and executed by artists of the first order, the high walls and high windows admitting a flood of light and rendering inspection thorough and easy. Mechanical devices were in operation for showing contraction of muscles; for explaining the action of the nervous system and the differences between mere reflex action and an action involving the cooperation of the higher nerve centers; for showing the circulation of the blood by a system of capillary glass tubes and the amount of work done by the heart; for demonstiating the function of the special senses and the mechanism of respiration and of voice and sound production. The subject of nutrition was given a prominent place. The more elementary chemical substances constituting the principal natural food products were shown in glass bottles and, further, shown by charts to which the percentage number of each elementary substance was attached, with the daily amounts of each required by man. Against a wall, there were arranged the quantities of water, salts, proteids, fats and carbo-hydrates which man consumed in a year and in the form of natural foodstuffs. At another table we were introduced into the mysteries of food adulteration and shown how cinnamon was made out of brick dust, pepper out powdered linseed oil-cake and strawberry syrup without strawberries.

CARE OF CHILDREN IN THE MIDDLE AGES.

COSTUMES OF MODERN TIMES.

THE IDEAL WORKMAN. By Professor Hosaelus, Berlin.

The toxic substances contained in alcohol, tea, coffee and tobacco and their influences on longevity and human happiness were all exhibited in a most tangible form. Table and kitchen utensils of the most varied composition and form were shown in separate cases.

A special group was devoted to housing, showing the best methods of heating, ventilating, illuminating and cleaning our dwellings.

In the group of occupational hygiene the visitor was shown the dangerous influences to which workmen are exposed in the different factories and the beneficial appliances recently devised and put into operation to prevent them.

The visitor was thus prepared to pass into the section in which the common infectious diseases of man were shown, how they originate and how they are best prevented, at the same time exhibiting busts of the

most noted men of science who have contributed most to our knowledge in this department of sanitation.

A most noteworthy feature also was the development, care and best mode of nutrition for nurslings: it was here shown that the care for the child must begin before birth and must extend to the mother. Of great interest were the demonstrations given on the subject of nutrition of the nurslings: their weight and size, the treatment of the diseases of children, the care of the skin, the duration of sleep, etc.

A most telling story is also told on the subject of dental hygiene.

The department of the general care of the body to be observed during childhood, adult manhood and old age is most impressive and so plainly told and shown as never to be forgotten.

When we add to all this that daily demonstrations in every one of these groups were given by the most eminent men of science, engaged for the whole time of the exposition, it is easy to explain the ever-increasing number of visitors to this hall and the fact that, towards the last part of the exposition, the hall had to be opened at night on special admission tickets, sold, to satisfy this ever-increasing thirst for knowledge. It simply had become thoroughly recognized that it was within the capacity of every man and woman to accumulate, in this hall, sufficient knowledge of the laws of health to provide for oneself that modicum of health which forms the most solid foundations of all human happiness. It had become realized as never before that health means bodily, mental and moral perfection, its cultivation resulting in strength, beauty and happiness.

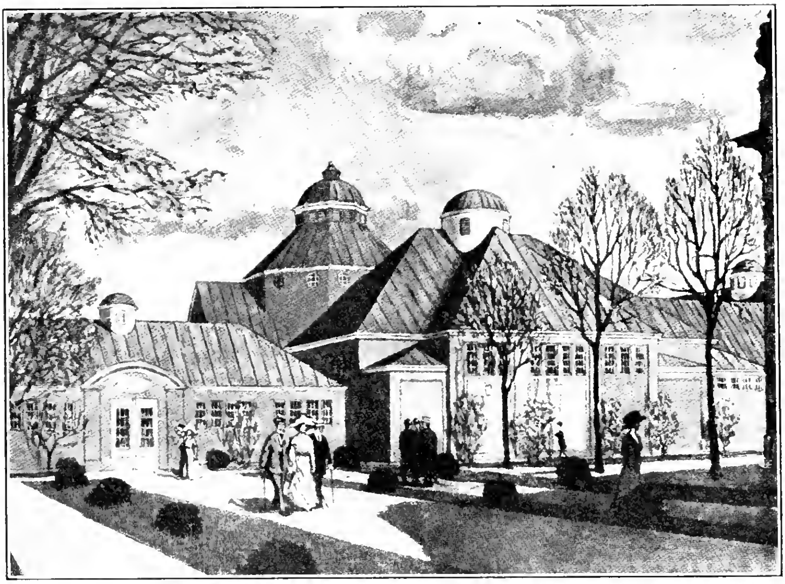
Foreign Pavilions

Amsterdam.—The city of Amsterdam had contributed valuable exhibits. The most interesting from the hygienic viewpoint were undoubtedly those of the city health office, consisting in tables, curves and microphotographs, the results of the chemical and bacteriological examination of food-articles and condiments; the control of infectious diseases and the ways and means employed in fighting their spread. Most interesting also were the exhibits demonstrating the difficulties experienced in Amsterdam with regard to its water-supply and the ingenious methods employed by its people to overcome them.

Brazil.—Those unacquainted with the amount and high character of work done, in recent years, in Brazil, by the public health authorities there, were surprised to see the wonderful exhibits in the Brazilian pavilion and to witness the daily kinematographic demonstrations of the actual field work done in that country, to fight yellow fever and other infectious diseases. The sanitary service of Brazil seems to be well organized and the work is done by the most improved methods and with the use of modern instruments. Completely equipped laboratories of bacteriology, chemistry and pathology are at the command of the sanitarian. Thus, under the sanitary supervision of Dr. Oswaldo

Cruz, now continued by that of Dr. Figueiredo de Vasconcellos, the pioneer leaders in this work, Rio de Janeiro is now free from yellow fever and one of the healthiest cities on the Atlantic coast of South America.

China.—The government of China, through the erection of its beautiful pavilion, filled with exhibits covering all the present departments of hygiene in the Chinese Empire, has succeeded in demonstrating its interest in and desire for the introduction of hygienic methods into the country. The members of the Chinese commission



HALL FOR WORKINGMEN'S INSURANCE. IN THE REAR THE HALL FOR CHEMISTRY AND SCIENTIFIC INSTRUMENTS.

have been instructed by their government to study hygiene and sanitation in all the European states, with the view of applying these methods to the needs of the people inhabiting the Chinese Empire. The opportunities for the beginning of such a study could never have been more advantageous than they were at the exposition of Dresden.

England.—Under the high protectorate of H. R. H. Princess Christian of Schleswig-Holstein and the presidency of the Right Hon. The Lord Mayor of London, a British National Committee, numbering about 250 members, was formed at the eleventh hour, for the purpose of giving the British people an opportunity of giving expression of their sympathy with the exhibition and its high aims, by contributing their exhibits and thus largely adding to the completeness of the results of the undertaking. Being an almost daily visitor at the British pavilion for several weeks, and, attending the daily demonstrations by Dr. Armit, I can not but express my great admiration at the completeness

of the exhibit got up in so short a time and covering almost every department in hygiene. A pavilion several times its size could scarcely have held any more than did this small pavilion of Great Britain. Much of this success, of which the British people may feel proud indeed, is no doubt due to the personal efforts of Sir Thomas Barlow, The Right Honorable Lord Ilkeston, Professor G. Sims Woodhead, the executive committee, and to the untiring energy of its skilful and learned executive secretary and demonstrator, H. W. Armit.

France.—The pavilion erected by the government of the Republic of France, was one, characteristic of the eighteenth century French architecture, designed by M. Tronchet, the architect-in-chief of the French government. Beautiful in construction and appearance, it was further favored by location.

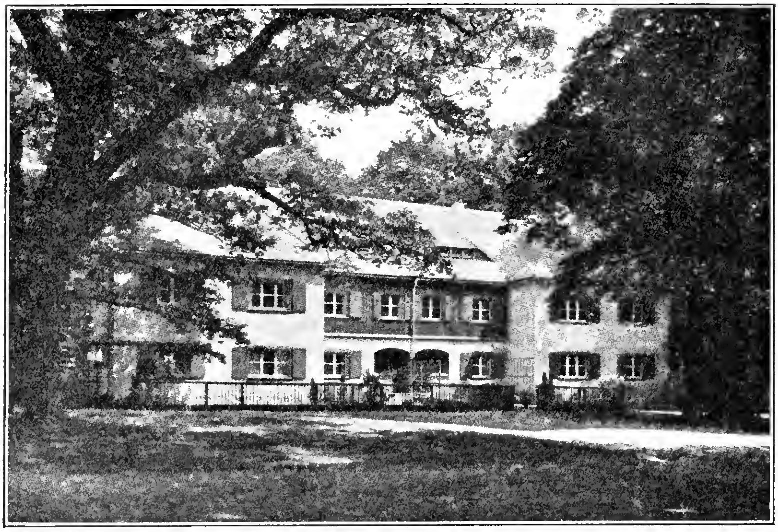
The French executive committee, of which Professor Fuster was chairman and Drs. Calmette and Landouzy members, had been obliged to adhere to a program of exhibiting none but objects of an administrative and philanthropic character. If industrial exhibits were nevertheless accorded a place they only served the purposes of demonstrating the progress made in technique employed in vaccination, disinfection, canalization, sterilization and the methods of water-supply.

The bulk of the exhibits consisted in collections of drawings, paintings, photos, models, relief maps, charts, showing the achievement of French scientists along hygienic and philanthropic lines. A most creditable as well as a most beautifully arranged exhibit.

Japan.—The pavilion of Japan, planned by Dr. ing. C. Ito of Tokio and executed by Alfred Pusch, Dresden, was characteristic of the country, simple, impressive, artistic, economical as well as adapted to its purposes. The commission sent by Japan consisted of eight representatives of the government, famous for the work they had done in their respective lines and one of the best known among which was Professor Dr. Miyajima, of the Imperial Institute for Infectious Diseases of Tokio.

The exhibits covered almost every department of hygiene, making this exhibition one of the completest in this respect among foreign pavilions. A fine model of Fujiama greeted the visitor on entering. The beauties of the country, its climate, were abundantly shown by models, drawings, pastels, photos, etc. The hygiene of nutrition, of clothing, the methods of housing and living, education of children in schools and homes, the care of the sick, safety devices, the prevention of epidemics, the history of development of medical sciences in the country all have received careful attention. But most impressive, if not positively inspiring, were the exhibits and background paintings showing the work of the sanitary corps while an action was in progress as well as that of the army field kitchen.

A special pavilion, "Formosa," under the special care of Dr. Takaki,



Six-family Tenement.

served to show the great sanitary improvements made by the government of Japan since it had taken possession of that island.

Italy.—In spite of the fact that Italy, during 1911, had to supply three different expositions of its own, namely: Rome, Turin and Florence, it found means of erecting and supplying a pavilion of its own in Dresden. The six groups into which the exhibits were divided were arranged in very good taste, giving and making a rather artistic impression. The exhibits were for the most part statistical and graphic.

Austria.—Austria's pavilion was one of the largest and perhaps the richest of all the foreign pavilions erected at the exposition. It represented a *multum in parvo* of the whole subject of hygiene and no simple description could do it justice; we must refer to the special catalogue and guide, published by the administration, for a detailed list of the exhibits and of the distinguished names of their contributors, as well as the corps of managers who had charge of this pavilion.

Russia.—Russia had been one of the first foreign countries declaring its readiness to erect a special pavilion at Dresden. The pavilion is a two-story structure designed by Professor Pokrowsky, St. Petersburg, and forms perhaps the largest foreign pavilion. As regards the contents, we can only repeat what was said of the Austrian pavilion, namely, that they covered the whole subject of hygiene.

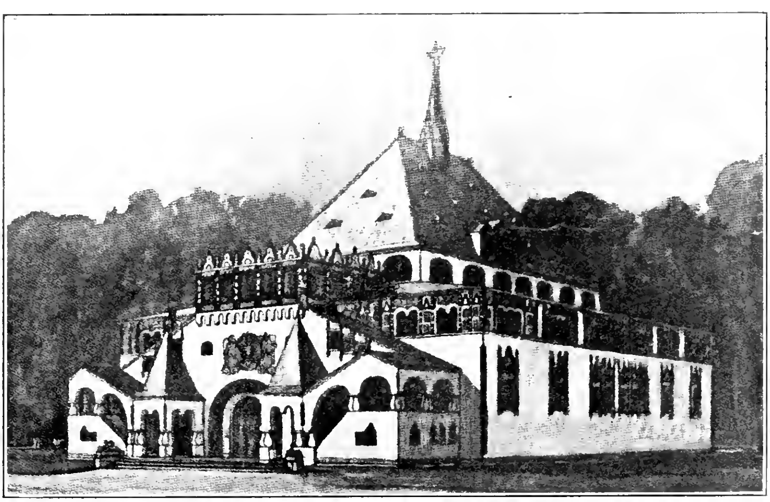
Switzerland.—The exhibitions in the Swiss pavilion were divided into ten chief and three special groups, extending over the entire field of hygiene. These exhibits served to place the small republic in the front rank of hygienic countries and reflect the greatest credit on its national committee of 100 and its executive committee, of which Drs.

H. Carrière, W. Kolle, Ost and Schaffer were members. Of quite special interest to military men was a new and quite well-adapted wheeled army field-litter.

Spain.—Spain had erected a neat-looking pavilion, the exhibits consisting for the most part of graphic and pictorial wall charts, statistical tables, etc., very artistically arranged. Drs. Pulido and Chicote, the Spanish representatives, received their commissions too late to enable them to collect a more representative exhibit. The exhibits nevertheless showed that Spain is awake to the progress in all departments of hygiene, plainly demonstrating its keen interest by its participation in the exposition in Dresden.

Hungary.—The visitor to the exposition would hardly have looked for a special pavilion representing Hungary after having seen the one erected by Austria. But so great was the interest of the Hungarian government in the exposition and its high aims at Dresden, so much had been done there in recent years to improve the hygienic conditions of its people and its institutions and so different from those of other countries were the hygienic requirements of Hungary, that the Hungarian exhibits, many of which were quite original, aroused and sustained the interest which they so well deserved. The special catalogue and guide, by Professor Emil von Grosz, covering 48 pages, must be allowed to speak for the rich collection seen in this pavilion. Special sympathy was aroused with the visitor on the subject of those institutions which were devoted to the governmental care of abandoned children. The Hungarian people believe that every abandoned child has a right to be cared for by the community.

United States.—If absence, ever before, was conspicuous anywhere, it was the absence of a United States pavilion at the exposition at



THE RUSSIAN PAVILION.

Dresden, 1911. The "humiliating blush of shame" anticipated in my letter to the American Public Health Association (*Am. Jour. of Public Hygiene,* Nov., 1910, p. 858) could be seen on the face of every American at the exposition and realizing the gravity of the situation. While the flags of every civilized nation could be seen floating merrily to the breezes, the stars and stripes were missing. The humanitarian eye among its stars played no part in, had no sympathy with, no contribution to offer for, this most Christian endeavor to raise the hygienic standard among the nations of the world, so fundamental to international happiness and international peace which we so loudly acclaim.

While the real cause of this may never become known, the stain, created by this demonstration of indifference, will remain a lasting reproach to the American people, especially to its public health officers.

THE VALUE OF NON-INSTRUMENTAL WEATHER OBSERVATIONS

By Professor ROBERT DEC. WARD

HARVARD UNIVERSITY

MUCH emphasis has been laid—and rightly—upon the necessity, in climatological studies, of systematic observations, carefully checked, punctually recorded and extending throughout many years, of properly exposed standard meteorological instruments. Upon such observations the scientific study of the world's climatology must be based. Without them everything remains vague: no real comparison of climates is possible; no detailed investigations of climate in relation to health, to crops, to industry, can be undertaken. Our conviction has become fixed that unless we can keep such a series of standard records, with a considerable and expensive instrumental equipment, it is not worth while to attempt any meteorological observations whatever. This is far from being the case. There is a very considerable series of observations—non-instrumental, unsystematic, irregular, "haphazard" if you will—which any one with ordinary intelligence and with a real interest in weather conditions may undertake. Such a diversion will add greatly to the interest of our humdrum every-day life, and will develop from day to day, in a surprising way, powers of observation which we were unconscious of possessing. Obviously, when such non-instrumental observations can be made at regular hours, at one place, they lead to a more compact and complete result than when they are made at odd times, in different places, as during a journey.

During the past summer, while recovering from a recent illness and therefore not wishing to burden myself with routine instrumental observations, I have found great satisfaction among the New Hampshire hills in working out day after day the local meteorological conditions. I have tried to banish from my mind altogether my previous knowledge of the climate of the region as a whole, and of the meteorological phenomena of mountain districts in particular. Thus, open-minded and unprejudiced, as far as possible, I have gradually worked out the essential elements of a local, non-instrumental climatology—an undertaking which has given me great interest, and I frankly confess has added not a little to my general store of climatological knowledge.

During the excessive heat of the first part of July (1911) it was comforting to note[1] that the maximum temperatures up in the New

[1] A sling thermometer was used in this case.

Hampshire hills averaged 3°–5° lower than at the Weather Bureau station in Boston, and that the nocturnal minima in the clearer air and at the higher altitude of my hillside were also several degrees lower than the disagreeably high minima of the city. The very regular occurrence of marked up-slope and down-slope ("mountain and valley") winds on all fine days; the increasing wind velocity towards noon and in the early afternoon, with calm mornings and evenings ("diurnal variation in wind velocity"), on these same days; the wonderful growth of cumulus clouds on the surrounding mountains and in relation to them; the development of cloud banners, cloud caps and cloud cascades; the effect of the general topography upon the local wind direction; the development of low-lying valley fogs at night, their gradual rise as fracto-stratus clouds and their dissipation under the morning sun; the marked difference, in relation to exposure to the cool nocturnal downhill breeze and to valley fogs, which neighboring house-sites exemplified; the apparent development of small local thunderstorms over the near-by mountains, while the larger thunderstorms came across these same mountains unaffected by the topography—these were a few of the many things which my very casual observations emphasized. Apart from these special subjects the general sequence of the larger weather changes resulting from cyclonic and anticyclonic controls was, of course, noted. So distinctly worth while has this simple and far from burdensome undertaking proved that I heartily recommend others to try it, but let it be repeated that real interest will come only if all previous meteorological knowledge of the region is, so far as possible, banished from the mind. And let me warn every one that he must beware lest his meteorological explanations run counter to the general traditions of the community. The location of most of the abandoned farmhouses in the region where I spent the summer, on the hillsides or even hill-tops, seemed to me to be most naturally explained on the theory that they were placed there in order that they might be above the cold and frost and fogs of the valley bottoms. One of my neighbors, who firmly believed that these houses were placed on the hill-slopes so that their original owners might have early warning of the approach of Indians, has upbraided me with shattering all the old and romantic traditions of the place. Let me suggest, further, that a very simple study of the value, as prognostics, of many weather proverbs will prove an interesting occupation. Weather proverbs are good, and bad, and indifferent. Most of them are bad, that is, do not work at all. A large number are indifferent, that is, work both ways. Comparatively few are really good. It is well worth while to select a few of the best known proverbs and keep careful written record of the times that each one "hits," *and also of the times that each one "misses."*

Most people count the "hits" and disregard the "misses." If such a record be kept, the wheat will be separated from the chaff, but a week or a month of record, while long enough to bring out much of interest, is far too short a time for purposes of scientific comparison of relative values.

Travelers, even when passing rapidly through a country on the railroad, and, still better, when moving more slowly on horseback or on foot, usually have opportunities for making simple non-instrumental observations which will add greatly to the interest of their journey, and which, if the region is comparatively little known, may really be of considerable importance. I have long felt that what I have termed "car-window climatology" deserves far more attention than it has received. In my own experience when traveling in South America under conditions which usually made it impossible to carry any instrument except a sling psychrometer, it was found feasible, when journeying on horse or mule back, on the Brazilian "trolley," or in the train, to collect facts which added greatly to my understanding of the climatology of the regions passed through; made the trips alive and interesting, and helped to hasten the passage of many weary hours. Some of these observations, indeed, it has seemed worth while to publish. There are many observations which an intelligent traveler can make, even from a car-window, although a slower method of progression is, of course, to be preferred in such a study. Wind velocity may be reasonably accurately estimated, after a little practise, by noting the effect of the wind in blowing trees, or in producing waves of different sizes in lakes or on rivers. The prevailing wind direction can often be very accurately determined by observing the slant of wind-blown trees, or again, by taking note of the effects of wave action on the leeward side of a lake or pond. Vegetation always furnishes a *general* criterion in regard to temperature and rainfall. When trees shed their leaves we infer a season of cold or it may be of drought. The occurrence of frost may be detected both by seeing it, and by noting its effects. The altitude reached by frost may likewise be observed. The direction of rainy or snowy winds may be discovered by observing on which side trees are wet. Whether or not hail, or snow, or sleet, or frozen rain, or gales, or heavy rains, or fog, occur in a region is observable, so far as the period of his visit is concerned, by any traveler. Forest and prairie fires indicate droughts, or dry seasons. Tornadoes and high gales, may be detected many years after their occurrence by the damage they did to trees. Whether or not a river is subject to floods may usually be determined by such hurried observations as can be made from a car-window, by noting the mud deposited by former floods on the trunks of trees, or by seeing the banks and neighboring fields actually overflowed.

The condition of the roads, whether dusty or muddy, indicates in a general way the occurrence or lack of recent rainfalls. And thus, through a long list, we might go on. Non-instrumental, even irregular and scattering observations of meteorological conditions, and of their effects, are well worth while, if intelligently made. Such observations should be more generally undertaken.

During the short semi-vacation of the past summer I have found much interest in reading the "Journals" of the Lewis and Clark Expedition "to the sources of the Missouri, across the Rocky Mountains, down the Columbia River to the Pacific in 1804–06." What struck me particularly was the remarkably clear picture which I gained of the climatic conditions of the then unknown country through which, amid great hardships and many dangers, this famous expedition passed. The leader of the expedition was charged by the President with reporting upon very many matters besides meteorology.[2] Yet, in spite of the many difficulties of the journey, and with only one instrument—a thermometer—which was unfortunately broken before the end of the trip, the observing eye of Captain Lewis was able to note a variety of meteorological and climatic facts which give a vivid picture and emphasize, in a striking manner, the kind and the value of simple weather observations which any intelligent traveler can take.[3] In view of the many hardships of the journey, it is surprising to see how few gaps there are in the record, which covers the period January 1, 1804–September 30, 1805. Between May 14 and September 18, 1804, there comes the only considerable gap, with the significant comment: "The party were then just beginning the ascent of the Missouri, and it is probable that amongst the many other important things which engrossed their attention this was omitted." The tables give date, and thermometer, weather and wind direction at sunrise and 4 P.M.; also the rise and fall of rivers, in inches and feet.

The thermometer readings have, perhaps, less value than might be expected, partly because they could not be continued throughout the ex-

[2] President Jefferson instructed Captain Lewis to report upon climate as follows: "Climate, as characterized by the thermometer, by the proportion of rainy, cloudy and clear days; by lightning, hail, snow, ice; by the access and recess of frost, by the winds prevailing at different seasons; the dates at which particular plants put forth, or lose their flower or leaf; times of appearance of particular birds, reptiles or insects."

[3] Captain Lewis's scheme of notation of weather was as follows:

f, fair weather.
r, rain.
h, hail.
l, lightning.
c a s, cloudy after snow intervening.
c a r s, cloudy after rain and snow.
c, cloudy.
s, snow.
t, thunder.
a, after, as *f a r* means fair after rain which has intervened since the last observation.

pedition, partly because they were made but twice a day, and partly because it is unlikely that the instrument was always well exposed.[4] The highest temperature noted was 92° (July 31 and August 1, 1 P.M., 1805), and the lowest was — 45° (sunrise December 17, 1804). Clearly the expedition passed through a country of large annual and diurnal ranges of temperature (east of the Rocky Mountains). The summer afternoon temperature rose to 70°–80°, and even 90°, while in winter the sunrise readings were as low as — 20°, — 30° and even — 40°. The diurnal ranges are noted as having been extremely large among the mountains, and on one day a difference of 59° was noted between sunrise and 4 P.M. The prevailing summer type of weather was fine, warm or even hot days, with cooler evenings and nights; not infrequent thunder-storms, moderate to high winds, especially in the afternoons. The southerly winds are so often referred to that we have little hesitation in concluding that this is the prevailing direction in summer on the Great Plains, and we see at once, in our mind's eye, that great sweep of southerly and southeasterly winds, across the region west of the Mississippi River—the continental inflow of summer, in response to the pressure-gradient between the Gulf of Mexico and the interior of the continent. These winds are frequently described as of high velocity during the daytime, blowing the sand from sand-bars and river-banks. Within the past quarter-century these same winds have been harnessed for the service of man, and they are to-day driving hundreds of windmills on the Great Plains for pumping water for stock and for irrigation, for sawing wood and for grinding corn and wheat. Captain Lewis observed that "the winds blow with astonishing violence in this open country." We have learned since that their velocities are not only high, comparable with those along the seaboard, but that they are also very uniformly distributed through the year, and are "usable" for windmill purposes to a remarkable degree. But no more striking illustration of the wind velocities on the plains has ever been given than Captain Lewis's description of the occasion when one of his boats, which was being transported on wheels, was blown along by the wind, the boat's sails being set! Surely this account emphasizes the analogy between the winds of the ocean and the winds of the Plains. Both sweep over a surface of little friction. Both attain high velocities in consequence.

The frequent occurrence of rain in May and June emphasizes the season of maximum precipitation (the "Missouri Type" of Gen. A. W. Greely) which has since proved of such immense economic benefit

[4] It should be noted, however, that at the beginning of the table of observations, where the first data are given, for "Duboes," January 1, 1804, it is stated: "Thermometer on the north side of a tree in the woods." This surely indicates careful attention to exposure, when possible.

over this great region, for on the whole the most rain falls when it is most needed for agriculture. A different seasonal distribution of precipitation would banish agriculture from thousands of acres of land which are to-day giving our farmers good crop returns. The fact did not escape the watchful eye of Captain Lewis that the rainfall of the warmer months over the region which he crossed is essentially spasmodic and "patchy" in character, *i. e.*, is of the shower or thunderstorm type, as contrasted with the more general and widespread rains and clouds of the large storms which characterize the winter months over the country as a whole. It is this very peculiarity of "patchiness" of the warm-season rains which renders them disappointing to the farmers whose crops are suffering from drought. A half-hour shower, covering perhaps a very small portion of a state, is a terribly exasperating occurrence to those whose lands are "screaming for water," but are outside of the limited area covered by the rain. Further, the fact that there is "very little rain or snow either winter or summer," is a sufficient emphasis on the general decrease in the rainfall to the west of the Mississippi River, which is so marked a feature on our mean annual rainfall maps. Captain Lewis paid particular attention to thunderstorms, in which, probably because of their violence, he seems to have been much interested. On April 1, 1805, he wrote, "I have observed that all thunder clouds in the western part of the continent proceed from the westerly quarter, as they do in the Atlantic states." This is perhaps the first specific mention of this important meteorological fact. On May 18, 1805, the record states: "We have had scarcely any thunder and lightning; the clouds are generally white, and accompanied with wind only." This we may take to indicate that the season of maximum thunderstorm activity had not begun, the clouds were doubtless our typical summer cumulus clouds, which, being best developed when the wind is strongest, *i. e.*, in the warmer hours, are often called "wind clouds." A thunderstorm which occurred on June 27, 1805, receives special mention. This storm lasted two hours and a half, and was accompanied by hail about the size of pigeons' eggs, which covered the ground to the depth of 1½ inches. Some of the hail-stones rebounded from the ground to a height of 10 or 12 feet. Several of the men were knocked down and bruised; some got under the canoe for protection, and others covered their heads. One hail-stone weighed 3 ounces and measured 7 inches in circumference. The stones were generally round, and perfectly solid. Captain Lewis adds: "I am convinced that if one of these had struck a man on his naked head it would certainly have fractured his skull." On July 6, 1805, another thunderstorm brought hail which covered the ground and was near the size of musket balls. One blackbird was seen to be killed by the hail,

and Captain Lewis was "astonished that more have not suffered in a similar manner."

Our general understanding of the essential climatic characteristics of the country through which the expedition passed, already reasonably accurate although only in outline, becomes clearer as we pick out other details which are noted in the journals. "The air is remarkably dry and pure in this open country. . . . The atmosphere is more transparent than I ever observed it in any country through which I have passed," Captain Lewis says, thereby bringing out very clearly one of the great climatic advantages of the region. The rapid evaporation, which has its disadvantages as well as merits, was frequently observed. Thus (September 23, 1804) on one occasion "in 36 hours 2 spoonfuls of water evaporated in a saucer," and elsewhere in the "Journals" we note that the rapidity with which Captain Lewis's ink dried up was recorded as furnishing a striking illustration of the dryness of the air. Surely that gives us a hint as to what can be done by a traveler who is alive to what is going on around him. The difficulty of making any accurate estimate of distances in the air of the mountain country, so much drier and purer than that to which he had been accustomed, struck Captain Lewis forcibly. Similar difficulty has been experienced by many persons whose eyes have become trained to estimate distances in turbid air near sea-level, and find, on mountain tops, that their whole scale of distances must be revised in order to allow for the greater clearness of the mountain air. Although the winter was spent on the Pacific coast, there was no lack of opportunity to observe frost and cold on the Plains and northern plateaus. Frost we find recorded as "white," "hard," "very hard." The thickness of ice frozen in a day is often recorded. On October 18, 1804, we note that water in vessels exposed to the air was frozen, as was "the clay near the water edge." And on another occasion (April 15, 1805) "the earth at the depth of about 3 feet is not yet thawed, which we discover by the banks falling in and disclosing a strata of frozen earth." It was recorded that snow fell on the mountains while rain fell at lower levels—a common phenomenon resulting from the lower temperatures aloft. The occurrence of nocturnal radiation fogs; the prevalence of cold northwesterly winds in the colder months (as contrasted with the warm southerly and southeasterly winds of summer); the depth of snowfall; the appearance of auroras, and of haloes and other optical phenomena; the migrations of birds; the coming of rains with northwesterly winds (this being a combination which is not very common in the eastern United States, but occurs more frequently in the west)—these are a few of the many instructive observations which have been picked out in a rather haphazard way from the very rich harvest in the "Journals." The occur-

rence of a heavy dew near the Falls of the Missouri is attributed to the greater dampness of the air in that place resulting from the spray produced by the falls. This reminds one of the reported appearance of dews in the vicinity of desert oases, and of the tradition that travelers across deserts have often been assured of their approach to an oasis when they have observed that dew forms at night. The frequent firing of the grass on the Great Plains by the Indians is often referred to, but there is no reference to the possible effects of this custom upon the treelessness of the region.

The winter time which was spent by the Lewis and Clark Expedition on the Pacific coast, at the mouth of the Columbia River, gave Captain Lewis abundant opportunity to observe the meteorological and climatic peculiarities of that region, and to contrast them with those with which he had become familiar in the east. "The loss of my thermometer I most sincerely regret," he wrote on January 3, 1806. "I am confident that the climate here is much warmer than in the same parallel of latitude on the Atlantic Ocean, though how many degrees it is now out of my power to determine." A few days later we read, "Weather perfectly temperate. I never experienced a winter so warm as the present has been," and note is made of the fact that the Coast Indians wore, and needed, less clothing than those east of the mountains. Clouds, and heavy rains and gales—much changeable stormy weather and very little sunshine—made such an impression that Captain Lewis wrote, "The vicissitudes of the weather happen two, three or more times in half a day." The early part of the winter was so mild that, as already noted, it could not fail to attract attention for that reason. There being no ice, meat was smoked in order to save it, and even that method was by no means uniformly successful. Later on, however, we find frequent mention of greater cold, of snow and of "hail" (frozen rain?). On January 28, 1806, a vessel of water was exposed in order that the thickness of ice might be measured. Unfortunately, the water was only two inches deep, and it froze to the bottom. "How much more it might have frozen had the vessel been deeper is therefore out of my power to decide," was Captain Lewis's interesting and critical comment. It is clearly stated that the winds from the land were cold and clear, while those obliquely along the coast or off the ocean brought warm, damp, cloudy and rainy weather. Thus a significant climatic control received early and explicit recognition. Later in the winter (March 6) this earlier statement was qualified as follows: "Easterly winds which have heretofore given us the only fair weather we have enjoyed seem now to have lost their influence in this respect." The strongest winds came from the southwest. There is further an interesting statement to the effect that a certain harbor was not protected

against southerly and southeasterly winds, but as these seemed to be winter winds the harbor would doubtless be safe in summer. The explanation, which could not be given in Captain Lewis's time, is to-day found in the frequency of strong southerly winds during the cyclonic storm season (winter) of the Pacific coast. If any one can read Captain Lewis's weather record for the northern Pacific coast without gaining from it a vivid idea of the cloudiness, the heavy rainfall, the high winds, the small amount of sunshine and withal the mildness of the winter of the particular district which the expedition encamped, he must be a hopelessly unappreciative and unintelligent person.

In looking over what I have written on the weather records of the Lewis and Clark Expedition, I realize that I have failed to bring out, with any of the clearness which it was my hope to secure, the climatic picture which Captain Lewis makes so distinct and so interesting. In spite of the deficiencies in my presentation, I hope, nevertheless, that I have to some extent succeeded in emphasizing the value of non-instrumental meteorological observations.

NARROW JAWS AND SMALL FEET

By RICHARD COLE NEWTON, M.D.
MONTCLAIR, N. J.

A FEW simple precautions in rearing our children would redound to the development of the race in quite unexpected ways. The writings of Bogue and others have proved that the small jaws and irregular teeth of Americans are due to the simple fact that the teeth and jaw bones have never been developed by chewing hard foods as nature intended us to do. As one consequence of this non-development, the teeth are poor in their chemical constituents, which, added to their irregularity and consequent non-occlusion, renders them so prone to decay that a middle-aged man or woman with a complete denture (*i. e.*, 32 teeth) is so great a rarity that dentists are wont to rejoice when they discover such an one, even as the angels are said to do over one sinner that repenteth. In like manner the chiropodist might be supposed to rejoice, if one in his humble calling has the springs of joy within him, over the equally great rarity, a perfect adult human foot. For there is only one other thing so generally distorted and defective as the average human jaw, and that is the average human foot. We bring our children up to despise the Chinese who deliberately distort and malform the feet of their female children. Our virtuous conversation incites in our children's minds a horror of the foot-binding process by which the Mongolian parents prevent the natural growth of their daughters' feet and thus improve (sic) upon nature, and yet we allow our daughters to wear so-called Cuban heels and French heels and pointed-toed shoes, sometimes called one-toed shoes, until their feet are as truly malformed as the Chinese woman's, albeit in a less degree.

There seems to be more logic in the Chinaman's distortion of the foot than in that of the occidental races. We are assured that no Chinese woman of rank can expect to marry well if she has natural feet, like a working woman, any more than our girls expect to marry well if they have a natural waist. A Chinese lady of high degree abroad upon the highways must be attended by two or three maids or helpers supporting her, to show to the admiring multitude that she can not walk without help. This is what her feet have been compressed for. This proves that she is a lady and fully fitted to marry a gentleman of rank and attainments. The gentleman, on his part, has also taken pains to show that he is incapacitated for manual labor. His finger nails have been allowed to grow to an incredible length and for fear that they may

be broken and look stubby, like a laboring man's he has small cases made, I believe, of ivory or some fancy wood, to draw on over those prolonged nails and preserve them intact.

Americans do not seem to be quite so anxious to prove to the outside world that they are incapable of walking, or of manual labor, as the Chinese, but they are extremely desirous of looking chic, smart and up-to-date, and we have seemingly as great a horror of feet which have grown to their natural size, as the celestials. We uniformly buy our shoes from a size to a size and a half too small for us. We do not realize that our feet should spread, not the toes alone, but the whole foot, like an animal's paw, with every step we take. Why we have the insane delusion that our feet should be small, out of all proportion to our bodies, no one so far as I know can explain. Orators have praised small feet, and poets have sung to them. Fashion plates have depicted them and lovers have sighed for them, and really from want of proper use, from compression and from the consequent arrested development because of their being encased in unyielding leather boxes from early childhood, our feet are much smaller in proportion to our size and weight than they should be. But this is not all. By reason of the absurd pointed-toe shoes, which men and women both wear, man is becoming practically a unidactylous animal. That means that we cultivate our great toes and let all the others atrophy for want of use, when they are not doubled up or twisted over each other so that standing on the feet for any length of time, not to mention walking, is exceedingly painful and sometimes impossible. In these cases the pointed shoes have been adopted after the smaller toes have grown somewhat, and like those of the unfortunate Chinese girls, they must be crowded out of the way, for no genteel person in either China or America can afford to have the toes spread out as nature intended them to be. Often, however, the pointed shoes have been worn in early childhood and the poor little toes, in consequence, have never developed, and are only rudiments of what they should be. In the classical foot the second toe is longer than the first, the third toe is the same length as the first and the fourth and fifth toes are well shaped and free from corns and spread out and take good hold of the ground when the person to whom they belong is walking. This is an exceedingly important point. Our toes should spread apart, as said before, like an animal's paws when we put our weight on the forward part of the foot in stepping out with the other foot.

There should be plenty of room in the shoe for the toes to do this, and it is largely because the toes are so tightly confined in pointed shoes and can not spread out that Americans are such poor walkers. The ridiculous high heels are unsightly and injurious and make walking difficult, yet they do not deform the foot, the most beautiful and

exquisitely designed of all our organs except our hands, to the same extent as do the short and pointed shoes so commonly worn.

So far as walking for any distance is concerned, no American expects to do that. It is because the feet are so undeveloped and their ligaments and muscles are so weak, that so many people suffer with flat feet or with weak arches. So that now, all the shoemakers are putting steel arch supporters in the shoes. This is about as sensible as it would be to support a weak arm by binding it up in splints and making it immovable, hoping that if it could not be raised, it would gradually grow strong and robust. Even a shoemaker would laugh at such a method of making a child's arm strong, and yet he boasts that he makes a weak arch strong by preventing it from taking its natural exercise. The arch of the foot must go down whenever one bears his weight upon it, and the foot must spread out. For long tramps nothing could be more painful than shoes with metal arch supporters in them. Like all these attempts to interfere with nature's methods, of which man, not to say woman, has ever been guilty, wearing arch supporters may be a cause of terrible suffering, if one has to walk any distance with them in his shoes or boots.

Of course if people walk very little, they can endure the arch supporters, just as the women endure the high heels. It would seem that ordinary boots and shoes are not made to walk in, but to look at, or perhaps to ride in.

I knew a Hebrew gentleman on the frontier who sold a man a pair of riding boots. In a few days, the purchaser of the boots came back complaining that the seams of his new boots had burst out, whereupon my Semitic friend, with a look of mingled horror and surprise, broke out with, "Why my frent, you didn'd valk in dose boots, did you? Dose was not valking boots, dey was riding boots." I often think of this occurrence when I see women trying to walk with Cuban heels and shoes far too short and too narrow for them. That their gait is singularly stilted and ungraceful every one knows, yet how they manage to walk as well as they do is surprising. I can nearly always tell by a woman's gait whether she is wearing shoes that really fit her or not. A woman properly shod may and often does show the queenly dignity and lissome grace which should characterize the most graceful of God's creatures. However, as an old walker myself I have to say that for good walking the human foot and ankle need a more thorough development than they are now allowed to attain. Every one of the ten toes should be allowed to grow to its proper size and should exert its due pressure on the ground when we walk, jump or run. The natural foot is a perfect arch, and its two columns the ball of the foot and the heel should be on an exact level, which means that the heel of the shoe should not be over a half inch in height. The heel of the shoe

should also be large, in fact, nearly as broad as the broadest part of the sole. The inside of the shoe should be three quarters of an inch longer and a half inch broader than the foot that it is meant to cover. Incidentally, people that wear such shoes and learn to take hold of the ground with their toes do not fall down and break their bones in slippery weather.

A friend of the writer's, a middle-aged man who has had his share of falls on slippery steps and icy pavements every winter, last winter escaped without a single hard fall because he was wearing low-heeled, broad-toed shoes, which the shoe-maker assured him were "a size too big for him." Here is a hint of value for stout people who are afraid to go about in slippery weather and who can not always have on a new pair of rubbers.

Just as our jaws suffer from non-development, which is the foundation of our adenoids, mouth breathing, poor digestion and mal-assimilation, not only because of our poor and irregular teeth, but because we do not get enough oxygen in our systems when we are growing for proper development, so we suffer from weak and malformed feet because these have not only not been developed by exercise, but have not even been allowed to grow to their natural size. Then we wear an arch supporter to still further cripple a weak foot and wear high heels under the mistaken impression that they keep up the instep. Of course when the arch gives way, as it often does because it is too weak to spring back after it has spread out in stepping under the weight of the body, a supporter in the shoe must be temporarily worn. Yet every effort should be made to strengthen that arch by running, walking on the toes in the bare feet, applying massage and electricity to the muscles of the calf, and toning up the general system.

The breaking down of the arch is really of more significance as an indication of general bodily weakness than as a local deformity, and its treatment should be quite as much general as local.

We shall not get perfect manhood or womanhood until we obey nature's obvious laws and allow our children's feet and jaws to develop as they were intended to do.

THE CONFLICT OF ADMINISTRATIONS

By President FRANK L. McVEY
UNIVERSITY OF NORTH DAKOTA

IN a letter to the governors of the states, at the close of the revolutionary war, Washington fervently prayed for four things, which he humbly conceived as not only essential, but actually vital, to the existence of the United States as an independent power. These four things were: an indissoluble union of the states under one federal head; a sacred regard for public justice; the adoption of a proper peace establishment; and the prevalence of a civic and friendly disposition among the people of the United States which will induce them to forget their local prejudices and policies, to make those mutual concessions which are requisite to the general prosperity, and in some instances to sacrifice their individual advantages to the interests of the community.

None of the revolutionary fathers could see difficulties other than those of a sea-coast commerce policed by many petty sovereigns. The problem of cooperation between the federal authority and the states would, in their opinion, arise only when brought to the surface by a state jealous of its prerogatives, never through the action of the federal authority. A hundred and twenty-five years have passed, and not only has the unexpected happened, but persons and corporations engaged in commerce seek the extension of federal power at the expense of state authority, if need be, in order that commerce may go on unhampered and free from restrictions of a territorial character.

Men rang the bells in steeples and gave utterance to their jubilation in loud hurrahs when King George's fleet left New York harbor. They had forgotten that a nation did not exist; that effective cooperation had ceased when Washington disbanded his army in 1783; that the union which was then dissolved existed only as a tradition, while the states were thirteen independent sovereigns, jealous of each other and open to the abuses of foreign intrigue. Thus at the beginning of the twentieth century in America has arisen a new type of problem in the conflict of administrations, solvable only by a process of cooperation.

Writing to Duane, Hamilton declared "the fundamental defect is a want of power in congress. Three causes contribute to this misfortune. In the people a jealous excess of the spirit of liberty, in congress a diffidence of their own authority, and a want of sufficient means at their disposal." "The clear duty of congress," declared Hamilton, "was to usurp powers in order to preserve the Republic, but its courage stopped

short of this solution, while the confederation as it stood was fit neither for war nor for peace."

The problem confronting the people of America in 1783 was the conversion of a voluntary league of states into a firm union. They needed to be first awakened to the necessity of organization and the adoption of a national policy; and after this the instrument of agreement must be drafted and the government established. It is not necessary at this time to discuss the detailed story of the constitution's making. From the beginning of its inception, men took opposite views as to the rights of the individual states and the nature of the powers that should be given to the central government. Those who upheld the idea of state's rights feared in their hearts the rule of the people. They argued for state representation in the national congress while maintaining that federal authority should be reduced to a minimum. The federalists, on the other hand, insisted upon a broad interpretation of the powers of the national government, thereby creating a controversy which furnished the basis of modern party relations, until materially modified by the tendency, brought about by the civil war, to discuss the import of questions rather than functions of government. The same motive, however, which caused men to turn to the states in the earlier day now causes them, in a measure, to look to the federal government, since it is believed that, in some degree at least, the rule of the people can be materially modified.

For a period of nearly thirty years after the civil war government in the United States, both federal and commonwealth, was used largely as an agency for the promotion of wealth. Special privileges came to overshadow common rights, and many problems were left untouched because in the opinion of the courts of the day the federal government had no authority over them, and the states by the constitution were not authorized to deal with such problems. But as industry has grown in immensity and spread its organization from commonwealth to commonwealth, producing a series of new problems in the movement of commerce from state to state, there has arisen a friction and questioned authority between the two branches of government in the United States. The constitution of the United States provided that the states should have all the rights of government, with the exception of the right of secession, impliedly determined by the results of the civil war, those powers which the constitution expressly confers on the federal government, and those which the constitution withholds from the states. It did not take many years for shrewd lawyers to discover that there existed in the interpretations of the two court systems a "twilight zone," as it has been picturesquely put by one of America's party leaders.

The specific powers of the federal government were determined narrowly, while the general powers of the state were interpreted specif-

ically. There arose, as a consequence, certain types of problems, certain species of acts, to which no special law seemed to apply, which left their authors in the possession of concerns working in a no-man's-land. To meet this serious difficulty it has been proposed on one side that there shall be a marked increase of federal authority which will deal with all such problems, and on the other there has been insistence that the sanctity of the constitution shall be maintained, the sacredness of the judiciary upheld, and the doctrine of the division of powers kept intact.

Those who believe in an increase of federal authority have maintained that the union is a federal one, that the sovereignty of the states never existed, and that with their present authority and power they are merely nuisances clogging the way of the federal government. There is no question that a series of difficult problems have arisen which demand a wider interpretation of federal authority, but the attitude just mentioned would result in the reduction of the states to mere local administrative units with no more power and authority than that possessed by a county or township. It is declared that the conservation of resources is so important that state lines ought not to be taken into consideration in dealing with the problem, while interstate commerce and the questions that are associated with it make it impossible, if we are to be a great commercial nation, to recognize that state authority over commerce and trade exists within certain boundaries.

Such, briefly stated, is the controversy; in its final solution the whole theory of American government is carried with it. In the course of the discussion it will be necessary to examine some of the experiences and outcomes of federal legislation, and to present, if there be any other point of view, what can be done in the development of cooperation between the two branches of government rather than subordination of one as compared with the other.

Over and above every other problem of a national character, in its importance from the point of view of the public, stands, in all probability, that of interstate commerce. The legislation and various attempts at legislation in this connection cover a period of forty years. In the year 1872 Mr. Regan, a congressman from the state of Texas, presented a bill regulating interstate commerce carried on railways. The bill was the outcome of grievances and difficulties arising from the attempts of the various states to secure some betterment of transportation facilities, lower rates and better methods of carrying on the business. Annually for more than fifteen years this bill made its appearance in congress, and it was not until 1887 that the interstate commerce act was passed regulating railroads and railroad rates. Despite the complaints that were made regarding the inefficiency of this law, and the difficulty of bringing under it many of the problems that arose, no other legislation took place until the year 1903, and since then the law has been modified in 1907 and 1910.

If we turn to the national bank act, which has been referred to many times as one of the most beneficent laws that the federal government has put upon the statute books, it will be noted that it had its origin in the necessities of the civil war, that it was developed as a revenue measure in the hope of forcing the banks of the day to buy the bonds of the distressed government. The principles which were recognized by the secretary of the treasury at the time as essential to the establishment of a banking system were taken in part from the experiences of Massachusetts and New York. Out of these came the right of free banking, the principle of the redemption fund, and the issue of paper money upon a bonded security, as important parts of the national bank act.

Passing in quick review the federal legislation relating to pure foods, it will be found that not until 1906 was any legislation secured which authorized the inspection and examination of foods by federal officers and placing upon adulteration an adequate penalty. For seventeen years the people of the nation had urged congress to pass a bill that would meet the many abuses that had arisen in the adulteration of food and dairy products. The same story can be told about the tariff. Since the civil war the different tariffs that have been enacted for the purpose of protecting manufacturers in the United States have steadily increased, and the percentage of the burden laid in the form of customs duty, regardless of the conflict of interests and the necessities of the consumer, has steadily augmented, until under the provisions of the McKinley bill it stood at a higher percentage than at any time in the history of the nation.

Nor is this all. The encroachments upon the financial strength of the states, in the form of added taxes, have come with the growing activity of the federal government, as might well have been expected. In the year 1909 the federal corporation tax was laid upon all corporations engaged in interstate business in the United States. It has been urged that a large revenue would be secured by this form of tax levy; that it would give greater control over the many corporations of the country, making it possible to reorganize their book-keeping and accounting systems along the lines of the best principles of accountancy. The law has now been in existence about two years, and it has been shown clearly that it lays a heavy burden upon corporations in the impossible demands of the accounting methods required, while the principle of self-assessment, now unchecked by government examination, leaves it practically with the corporations to determine what they shall pay. But the worst side of the corporation tax is that the fiscal system of those states that have developed such a plan of taxation is materially affected. These states find that their own sources of revenue are cut into, while the corporations subject to this fiscal control are provided with an argument of double taxation against proper state taxes. This phase of the corporation tax has been regarded by many economic

authorities as unfitting the tax for use by the federal government, and its application has been denounced in many quarters as an invasion of the proper field of state taxation.

In the efforts now being put forth to establish a federal income tax the same tendency is to be seen. While it can not be denied that the federal government should have the authority in time of need to levy a federal income tax, yet it is distinctly questionable as to the wisdom of such a tax in time of peace for federal purposes. The problems which confront the states at the present time are indeed serious. Upon them fall all of the burdens of maintaining local government, and these, with the growth of wider ideas regarding the development of society, constantly tend to increase rather than diminish. The states are now called upon to develop extensive educational systems, to care for the insane, to punish criminals, to maintain courts, to preserve order, to build roads, and support the poor, besides erecting public buildings, and in the municipalities providing water, light, paving and the other necessary improvements of modern towns and villages. To have the federal government, therefore, step aside and reach out into the states for additional funds for federal support means interference with the states' fiscal systems and in the long run the weakening of their financial power. In the customs duties and the internal revenue, the federal government has every facility to secure sufficient revenue for the conduct of its business.

What has already been said regarding the history of federal legislation in connection with the interstate commerce act, the national bank act, the pure food and dairy legislation, and the tariff indicates clearly the slowness with which congress meets the problems of legislation, and how difficult it is to secure modification of a law by a body so overwhelmed with legislation for a country as big as America. In nearly every instance the states began the legislation, and carried it forward to a point where it was necessary to look to congress for some wider interpretation in order that relief might be given. The work which congress has done, while commendable in many cases, shows clearly that it can not act intelligently in every instance because of its distance from the problem, and that while it does work out in general some specific lines of action, it can not by the very nature of things meet local needs.

Sixteen years after the introduction of the Regan bill came the interstate-commerce act, and for as many more no modification of the law was made, despite the insistent demands for such changes. The national bank act remained practically unchanged after the date of its passage until the year 1900. Examples of this kind go to show that federal legislation is attended by many disadvantages. Undoubtedly congress can deal with large problems on general principles, but on that very account it is often unwise for it to attempt to work out experiments and changes in the law.

It is just here that the states come to play an increasingly important part. They are in fact laboratories in which industrial and political experiments can be worked out on such a scale as to determine the value of the experiment. It means the relieving of the nation as a whole from many of the pangs necessary in the growth of democracy. It means the utilization of the best that comes from such experiments and the saving to the government of the loss of time and disappointment in carrying on large enterprises. The states have, as a consequence, an important governmental function to carry out. They are not to be regarded as mere administrative units, subject to the direction and domination of a federal authority thousands of miles away, with no autonomy such as is found in the case of the departments in France; but they are rather constituent parts of the union, self-directive, and capable of maintaining their own autonomy and of carrying on their own functions within their own boundaries. To them we entrust our daily welfare, while to the federal government are turned over our collective interests. Nevertheless, they are one and the same government, each a part of its frame, working together, but separately organized. To substitute one for the other is to violate the whole principle of the federal scheme.

The conflict between the two is more apparent than real. The difficulties of the situation have been materially exaggerated, and not always without a purpose. In the early history of our nation many of the believers in state's rights took that position because of their feeling that the government would not then be in the hands of the people, but would be only representative, and to-day that same feeling exists in the demand that the federal authority be enlarged and the states reduced to minimum power in order that again the authority of the people may be hampered and limited. Much confusion of detail and of procedure clouds the issue. Underlying it all, the principle of action, both in state and federal government, is the same. The law is founded on the common law of England, and there is to be discovered to the diligent inquirer a greater uniformity than diversity. The extent of this uniformity is marvelous. From one state to another have been handed on the principles of legislation and forms of government. In one state is initiated some new phase of political organization, its propagation is carried on into another community, and little by little there moves constantly over the land an increasing uniformity of legislation. While it may be said that as a nation we are face to face with serious industrial problems over which we have no central authority, nevertheless the nation has made some progress under present constitutional provisions and the states are diligently seeking legislation from other sources that will meet the difficulty. The danger is not from this direction, nor is it likely to arise from our failure to solve the problem in a fairly satisfactory way through the utilization of both state and federal governments, but the danger, if from anywhere, is from a

tendency seen now and then towards excessive centralization. It is not, however, from tyranny that we are likely to suffer, but rather from a breakdown in an organization too extended and too difficult of effective operation. There can be no question in the minds of students of political history that the future of the nation depends upon the cooperation of the governmental units rather than upon the exaggeration of one of them. Instead of attempting to magnify the federal government, there ought to be a marked movement toward the equalizing of the functions of both. Because of the extending of its authority over a large area, the federal government is in a position to secure information on all topics for utilization in the various states. An instance of this statement is found in the collection of data already undertaken by the different bureaus at Washington. With the authority of the national government behind them, they are able to bring together an immense amount of data that throws light upon many questions. To limit the functions of the federal government to the mere collection of data is not in the mind of any one. A second step could be taken, one that is already being carried on, through the medium of investigation. Thus the collection of data should be supplemented by specific investigations of various matters of interest to the public welfare. Again this alone is not sufficient. Such information must be given publicity, and here the federal government is in a position not only to give wide publicity to its own actions and the results of any investigations which it carries on, but is in a position to insist upon publicity on the part of all interstate corporations. Because of the conflict of authority in the field of commerce many suggestions have been made from time to time by which the federal government is to take over full authority in the matter of incorporating such corporations. It is urged in behalf of this movement that many of the states now permit the incorporation of companies under peculiarly satisfactory provisions for the company, and that as a consequence the other states are not able to control them. There is considerable truth in this position. But the matter is comparatively easily disposed of. There is no reason why congress should not pass an act setting forth the conditions under which any corporation may engage in interstate commerce. These conditions would have reference to capitalization, publicity of accounts, and responsibility for any statements set forth regarding their business. Such a law would in no way necessitate incorporation or the disturbance of the incorporation of companies by the different states. But like the tax upon bank currency passed in 1866, it would have a marked effect in forcing corporations to comply with the federal conditions, while at the same time allowing the states to modify the law so as to apply to the conditions peculiar to their own territory.

Many other instances might be cited in which the same relationships are to be found as in the case of the interstate corporations. The more

one studies the situation, the more one is impressed with the fact that the relations between the states and the federal government can be strengthened rather than weakened by the passage of laws on the part of congress which will set forth the conditions under which business concerns can enjoy the privileges of carrying on their traffic between the different states, allowing the regulations to be developed by the commonwealth. It might be argued that this would still retain the worst features of present conditions, without discrimination and with lack of uniformity. But an examination of the laws of the states will confirm the impression that the states are very rapidly taking over those regulations and laws which have been proved by the test of time to be satisfactory and efficient. Any limitations of the authority of a state like Wisconsin, where under the direction of an underlying public sentiment much progress has been made in working out a number of highly efficient methods of dealing with serious questions, would be unwise. It is very doubtful if the same progress could have been made by the federal government through the medium of legislation by congress.

The people of this country are interested in efficient administration. They are not insistent upon either federal or state authority as such. What they want to see is progress in dealing with some of our serious national questions. But history proves that when a nation tries to cover too large a field and through its national legislative body to deal in detail with local questions, it fails to accomplish the result that was expected. In America we have a very fortunate division of functions, at some points weak, but on the whole a satisfactory division of authority. To push the states down into the position of mere administrative units would result in the weakening of the whole plan of government and in a probable inefficiency because of the distance from central authority in dealing with governmental matters.

Our attitude, then, in this great question of the conflict of administrations should be that of seeking for the full utilization of both federal and state authority, for the elimination of friction between them, and for the securing of an adequate working plan by which both can be used to the best advantage. We are a nation of one people, believing distinctly in the federal form of government. It remains, therefore, for us to insist upon a clear understanding as to the functions of the federal government and a larger realization of the fact that the states are carrying the burden of the expense and difficulties of local problems, and that interference on the part of the federal government is likely to result in an increasing weakness of authority rather than a strengthening of government.

A century and a quarter have passed since the creation of the republic in 1787; the indissoluble union so fervently hoped for by the father of his country is now an accomplished fact; though the regard for jus-

tice can hardly be referred to as high, nevertheless the nation is making progress steadily toward more efficient courts; our peace establishment meets the needs of the republic; and great advance has been made toward the civic and friendly disposition among the people of the United States, sufficient to induce them to forget their local prejudices and policies enumerated by Washington as the fourth desideratum. We have still the problem of federal authority and the wise determination of what and how far the government should attempt to rule by central authority. The question is of vast importance; its determination will have much to do with the perpetuation of the republic.

RELATIONS OF JAPAN AND THE UNITED STATES[1]

By President DAVID STARR JORDAN
STANFORD UNIVERSITY

IT is now nearly sixty years since the modern history of Japan began. The arrival of Commodore Perry at Kurihama, the downfall of the Shogun and the restoration of the Mikado mark the point of transition from feudal Japan to the Japan of to-day.

In all this period, the Japanese nation has been the subject of intense interest to the cultivated people of America, and a warm sympathy has arisen between those people of each nation who have come to understand the character and the ideals of the other. This sympathy has been kept alive by the influence of Japanese students in America, on the one hand, and on the other by the interest of those who have gone as missionaries, as teachers or advisers in the affairs of Japan.

In Asia there has existed for many years a division of the non-Japanese into two sharply defined parties, or one may say, attitudes of mind, the pro-Japanese and the anti-Japanese. The disputes of these two types of people have not come to our notice until very lately. Till within the last decade, American influence was almost wholly ranged with the pro-Japanese. Contributory to this fact was our general tendency toward sympathetic interest in a nation which rose to constitutional government through influences from within. The Shimonoseki incident, the visit of General Grant, the aid of the United States in setting aside the obnoxious consular jurisdiction in the treaty ports, all these became expressions of the friendly attitude of America.

The Japanese question, as it is now called, first rose to the horizon in 1899, the year of the abrogation of consular jurisdiction.

The needs of cheap labor on the sugar plantations of Hawaii was great and constant. Kalakaua, the king, had tried to meet this need by "blackbirding" expeditions among the islands of Polynesia. The steamship companies followed by strenuous efforts among the laborers in the rice fields of the region about the Inland Sea of Japan, the districts of Okayama, Hiroshima and Yamaguchi. By their insistence and by offers of real wages their emigration agencies brought to Hawaii many men from the lowest stratum in Japanese life, next to the criminal and the outcast—the unskilled and homeless laborers in the rice fields. These have been called coolies, but their position in Japan was

[1] Abstract of an address at Clark University.

quite different from that of the coolies, the half slaves, of the continent of Asia.

These laborers were treated essentially as slaves in Hawaii. They carried with them none of the culture of Japan, they received none in their new homes. They did not go as colonists. The Japanese with homes do not willingly leave these homes where "their own customs fit them like a garment," to form new ones in another region. The Japanese are not spontaneously colonists. They will go to other lands for study or for trade or for higher wages. But they go with the hope to return. The coolies went to Hawaii solely under the incentive of higher wages. When Hawaii was annexed to the United States the shackles of their slavery was thrown off, and the same impulse of higher wages carried them on to San Francisco, Seattle and Vancouver.

In 1899, Mr. W. W. Scott, of Honolulu, a former resident of Japan, warned the Japanese authorities of the dangers involved in this movement of Japanese laborers to California. Their lower standard of living and of wages would make them exploitable. This would bring them in conflict with labor unions. Economic clash would beget race prejudice, and Japan could not afford to be judged by her least attractive and least efficient representatives. Influenced by these and similar considerations the Japanese government in 1899 refused passports to all unskilled laborers, and since that time none have come from Japan direct to the Pacific states.

But in response to the continuous demand of Hawaii they were for a time allowed to go there. Japanese people already constituted the great majority of the population of these islands. Even after passports were refused to laborers going to Hawaii, the immigration of coolies from Hawaii to San Francisco still continued.

There was and is a very great demand for Japanese help among the orchardists of California. No other labor has been adequate and available and it is not easy to see what the fruit interests are to do without Japanese help. In this work the European laborer has scarcely entered into competition. The prices paid the Japanese are not less than the wages of American labor in the same lines. The demand for Japanese workers in household service and in canning establishments has also been great and unsatisfied.

From the fisheries which the Japanese have almost monopolized in British Columbia and in Hawaii, they have been virtually excluded by statutes limiting the fisheries of California, Oregon and Washington to citizens of these states. Unless born in the United States the Japanese can not become citizens.

A large portion of the Japanese laborers avoided the orchards and established themselves in the cities where, as laundrymen, restaurant

keepers, draymen, carpenters and the like, they entered thus into competition with the American laborers, the most of whom in San Francisco were recent immigrants from Europe.

Their lower scale of living and their peculiarities in other ways soon brought them under the condemnation of the trade unions. Anti-Japanese societies were formed and much effort was spent to the end of the exclusion of Japanese and Korean laborers as the Chinese had already been excluded. The personal violence which accompanied the anti-Chinese campaign of twenty years before was practically absent from this. The Japanese were better able to take care of themselves and also, in spite of much reckless talk and exaggeration of language, there was very little real enmity toward the Japanese with any class of their opponents. Most of the unfriendly talk was for political purposes and the main cause of opposition was economic.

An exclusion act like that directed against the Chinese could not be considered by our government. It would be a needless affront to a friendly nation, and a nation willing to do anything we may desire, provided it could be done with dignity. The Chinese exclusion act finds its excuse perhaps in the fact that China is not yet a nation. No absolute monarchy can be a nation, in the modern sense. When China finds herself at last, this exclusion act must wholly change its form.

In this condition of affairs, a definite agreement was made with the Katsura Ministry of Japan, that no passports for America were to be issued to Japanese laborers, that the responsibility for discrimination should rest with Japan, and that all holders of Japanese passports should be admitted without question. This agreement has been loyally and rigidly kept by Japan. A bit too rigidly, perhaps, for it is growing increasingly difficult for Japanese students to come to America. The diffusion among our American universities of Japanese students, eager, devoted and persistent, has been one of the most important factors in maintaining the mutual good will and good understanding of the two nations. For everywhere these Japanese graduates of American universities give a good account of themselves, standing high in the estimation of their people at home, while retaining a keen interest and intelligent sympathy in all American affairs.

The present settlement of the immigration question is the very best possible, so long as restriction of any sort is regarded as necessary. It is in the interest of both nations and of all concerned, and the occasional efforts to supersede it by a general "oriental exclusion" bill are prompted by no consideration of the public welfare.

To be grouped with the inchoate nations of Asia as "orientals" is particularly offensive to the proud, self-governing Japanese. In their thoughts and ambitions, in their attitude towards peace and justice and

toward modern civilization, the Japanese are in full harmony with the nations of Europe. It is their mission to bring modern civilization to Asia. This they are literally doing in Korea, one of the most interesting experiments in the reclamation of a dying nation undertaken in modern times, comparable to our sanitation of the Canal Zone of Panama. At the same time, the hold of Japan on Korea, like our hold on Panama, rests on the right of arbitrary seizure.

The main justification of the exclusion of Japanese unskilled laborers must be found in the economic conditions on the two sides of the Pacific. It is our theory in America that there should be no permanent class of unskilled laborers, and that it is the duty as well as the right of every man to make the most of himself.

In most other nations, a permanent lowest class which must work for the lowest wages and do the menial service of society is taken for granted. This theory is affirmed in the Chinese proverb, "Big fish eat little fish, little fish eat shrimp: shrimp eat mud." It is no part of our policy that shrimps should remain shrimps forever. Cheap labor is exploitable to the injury of labor of a higher grade. There is then a degree of justice in the contention for the exclusion of the cheapest and most exploitable type of laborers, whatever their race or the country from which they come.

There is also legitimate ground for fear that a wide-open door from Asia would crowd our Pacific coast before the natural population of America has found its way there. Such a condition would add to the economic wealth of the coast at the expense of social and political confusion.

Many honest men fear the advent of large numbers of Japanese as likely to provoke racial troubles similar to those which exist in the south. I do not share this opinion. No race is more readily at home in our civilization than the cultivated Japanese. That the rice-field coolie does not assimilate is because of his crude mentality and his lack of any training, either Japanese or American. This is broadly true, though among these people are many of fine instincts and marked capacity. The condition of mutual help and mutual tolerance in Hawaii shows that men of a dozen races can get along together if they try to do so. The problem of the south is the problem of slavery; the problem of the half white, the man with the diverging instincts of two races, this status changed in an instant, by force, from the position of a chattel to that of a citizen. It is the problem of the half-white man given political equality when social equality is as far away as ever. No bar sinister of this sort nor of any other kind separates the European from the Japanese.

Social reasons for exclusion have a certain value. The Japanese are the most lovable of people, which fact makes them the most clan-

nish. They have the faults of their virtues, and the uneducated Japanese sometimes show these faults in unpleasant fashion.

There are still more urgent reasons why the Japanese themselves should insist on exclusion of their coolie laborers from Canada and the United States. The nation can not afford to have America know it by its least creditable examples. A hundred Japanese rice-field hands are seen in America, to one Japanese gentleman. Thousands of men who never knew a Japanese merchant or artist or scholar have come in contact with Japanese draymen or laundrymen. They have not always found these good neighbors. The present conditions are not permanent, perhaps, but as matters are to-day it is to the interest of Japan, even more than to the interest of California, that the present agreements should be maintained.

Just after the Russian War, when America's sympathy was almost wholly on the side of Japan because the attitude of Russia was believed to be that of wanton aggression, a series of anti-Japanese articles were published in various American newspapers. Who wrote these articles and who paid for them, I do not know, but their various half-truths and falsehoods had an unfavorable effect on American public opinion. All sorts of half-forgotten slanders were revived and followed in their wake. Among these is the ancient falsehood that Japanese banks employ Chinese tellers because they can not trust their own people. Of all the banks in Japan only one, the Yokohama Specie Bank, which does a large Chinese business, has ever had a Chinese employee.

The school affair in San Francisco was also unfortunate, although in itself of no significance whatever. In the great fire of 1906, the Chinatown of San Francisco was entirely destroyed. After the fire a temporary schoolhouse was established in the neighborhood. There were no Chinese children in this school and the teacher, perhaps fearing loss of position, asked the School Board to send the Japanese children in the neighboring region to her. The School Board, apparently ignorant of possible international results, formed of this an "Oriental School." There were no Chinese children concerned, nor is it at all clear that Japanese children would have suffered even had such been present.

Under our treaty with Japan our schools, as every other privilege, were open to Japanese subjects on the basis of "the most favored nation." To send Japanese children to an "Oriental School" was probably a violation of this clause of the treaty. It is not certain that this was a violation, but it appears as such on the surface. So far as I know, there has been no judicial decision involving this point. In any case, the apparent remedy lay in an injunction suit, and in a quiet determination of the point at issue. It was a mistake, I believe, to make

it a matter of international diplomacy. Neither the nation nor the state of California has the slightest control over the schools of San Francisco, unless an action of the school board shall traverse a national or state law or violate a treaty. A treaty has precedence over all local statutes. But the meaning of a treaty can be demonstrated only through judicial process.

The extravagance of the press in both nations stirred up all the latent partisanship in both races involved. On the one hand the injuries to the Japanese children were grossly exaggerated. On the other hand, gratuitous slanders were invented to justify the action of the school board. This action was finally rescinded at the request of the President of the United States, who uttered at the same time a sharp reprimand to the people of California. This again was resented by the state, as only five of its citizens were responsible for the act in question, and the people of the state as a whole had no part whatever in anti-Japanese agitation nor any sympathy with the men temporarily in control of affairs in San Francisco. The net result of the whole affair was to alienate sympathy from Japan. This again was unfair, for the Japanese nation as a whole had no responsibility for what, at the worst, was an error of judgment on the part of a few of its immigrants.

Since this affair was settled I have not heard a word as to the relation of the Japanese to the schools of San Francisco, and I presume that this difficulty, like most others, has disappeared with time and patience and mutual consideration. It is not likely to be heard from again.

Only a word need be said of other matters which have vexed the international air. War scares are heard the world over. The world over they are set going by wicked men for evil purposes. In general the design of purveyors of international slanders is to promote orders for guns, powder and warships. There are other mischief makers, who hope to fish in troubled waters.

A few years ago it was suggested in America that the Manchurian railways, built on Chinese territory, by the governments of Russia and Japan should be sold to China. To this end China should borrow the money of an international syndicate under whose authority the railways should be managed. This line of action was for various reasons impossible to China. The suggestion itself was very unwelcome to the Japan authorities as well as to the Japanese people to whom the leased land between Port Arthur and Mukden is hallowed ground, holding the graves of a hundred and thirty thousand of the young men of Japan. The suggestion itself was personal only. It was never acted upon, never approved by the American people, no official action was ever based upon it, and it should not be a subject of worry to either Russia or Japan.

The fur seal question has been under discussion for more than twenty years, ever since the wanton killing of females at sea first threatened the destruction of the Bering Sea herds. By the pelagic sealing of Canada the number of breeding seals in the Pribilof herd was reduced from about a million to about 180,000. The entrance of Japan into Bering Sea, for the protection of the herd, disregarding the regulations of the Paris tribunal, inadequate as these were, soon reduced these numbers to about 30,000. Last year, a treaty was concluded, Russia, Japan, Canada and the United States being parties to it, by which the matter was honorably and justly settled and the continuance and restoration of the three herds, American, Russian and Japanese finally assured. There is not now a single cloud above the official horizon as between the United States and Japan. There have never been any real difficulties and the apparent ones are no greater than must appear wherever great nations border on each other. As the Japanese are fond of saying: The Pacific Ocean unites our nations. It does not separate.

War talk on either side is foolish and criminal. Japan recognizes the United States as her nearest neighbor among western nations, her best customer and most steadfast friend. Her own ambitions and interest lie in the restoration of Korea, the safeguarding of her investments in Manchuria and in the part she must play in the unforetold future of China. For her own affairs she needs every yen she can raise by any means for the next half century. For the future greatness of Japan depends on the return of "the old peace with velvet-sandalled feet," which made her the nation she is to-day.

War and war demands have made her, for the time being, relatively weak, she who once was strong in her persistent industry, her unchanging good nature, her spirit of progress, her freedom from debt and in the high ambition of her people. Thirteen hundred millions of dollars in war debt is a burden not lightly carried. Through peace, and peace only, Japan will gain her old strength, and none know this better than the men of the wise and patriotic group who now control Japan.

SOME INTERESTING CHARACTERISTICS OF THE MODERN ENGLISH LANGUAGE

By ALEXANDER FRANCIS CHAMBERLAIN, Ph.D.

PROFESSOR OF ANTHROPOLOGY, CLARK UNIVERSITY, WORCESTER, MASS.

MODERN English possesses not a few characteristics of great interest from a psychological as well as from a merely philological point of view. This is especially true, if one considers the possible culmination of our mother-tongue as the world-language. For some of these traits are the very ones which seem fitted to enable English to survive in that rôle. They are matters connected with flexibility; correspondence with thought instead of subordination of it to grammatical categories and merely formal canons; power over words unknown to other tongues, where freedom in accepting foreign terms and liberty to "reduce" unnecessarily cumbersome expressions are often unhappily much restricted; absence of fear of hybrids and certain other misgivings of the "purists" and pedants. Altogether, English is a living language, master over both grammar and dictionary, and exceedingly skilful in its use of this sovereignty. But a few of these important qualities of modern English can be considered here.

1. *Foreign Words.*—The free adoption of foreign terms of all kinds is one of the most striking evidences of the real vitality and essential cosmopolitanism of modern English. Its vocabulary always has "the open door." It admits on the same conditions a word from Ojibwa or from Greek; one from Latin or from Polynesian. If the right word turns up at the right time, there is no Academy to pass judgment upon it, grammatically or lexicographically. The sole authority to welcome or to reject is the genius of the language itself. *Tammany* and *telephone, taboo* and *aeroplane,* all come into our common speech with equal rights to citizenship. English is thus dependent upon no one language, or even set of languages, for the accretion of its vocabulary. It can pick and choose wherever it will; no linguistic market is ever closed to its traffic. No one language, however polished, however important in the past history of the world, however highly esteemed by educators or approved by men of science, can assume the rôle of dictator here. The balancing of its draughts upon the classic languages with those upon insignificant or unknown barbarian tongues and dialects is a marked feature of the mother-tongue. English lets the psychological moment dominate; the needs of the time outweigh the prohibitions and the circumscriptions of the pedant. Thus Greek gave us *ostracise,* but not

the more living *boycott;* we owe to it *democracy, oligarch, aristocracy, tyrant* and *politics,* but we have borrowed from the American Indians *Tammany, mugwump,* and perhaps *caucus;* nor has anthropological science any greater words to conjure with to-day than *totem* and *taboo,* the first of which is derived from an Algonkian language of North America, and the second from one of the Polynesian dialects. To create *sociology,* a hybrid of Greek and Latin that shocked the purists was called into being, but the very useful and significant term *club* was taken from a cognate Scandinavian language. The familiar word *squirrel* goes back to Greek, but *chipmunk,* in spite of its rather deceptive appearance, is derived from the Ojibwa dialect of the Algonkian Indians. The Latin ending of *petunia* can not altogether disguise its ultimate origin from one of the Tupi-Guaranian languages of aboriginal Brazil. *Megatherium* is Latinized Greek, but *mammoth* is little changed from the form it had in a Tatar language of Siberia. The vocabulary of English owes much to Greek and Latin, but this debt does not include terms like the following, which have all become part and parcel of everyday speech: *Slave* (Slavonic) and *nabob* (Hindi); *talk* (Lithuanian) and *jungle* (Sanskrit); *thug* (Hindustani) and *bantam* (Javanese); *gong* (Malay), *tattoo* (Tahitian) and *guinea* (W. African); *alcohol, assassin,* and *tariff* (all Arabic); *buccaneer, cannibal, hammock, hurricane, mahogany, potato, tobacco, tomahawk, wigwam* (all from the various Indian tongues of the New World). What list of the important loan words of modern English could omit *Tammany, mugwump, totem,* etc.? And what place-name of classic origin has, in the present day and generation, been given new life and significance in our tongue, like *Chautauqua,* one of the remembrancers of the Iroquoian predecessors of the white man in the great state of New York? Another place-name from the same source, *Saratoga,* has also won lodgment, but with less fame and repute. In American English, in particular, the only memorial existing of some now extinct and forgotten tribe of savages may be some such word which has won a place in our hospitable lexicon. On the other hand, the united efforts of all the "purists" in the land are often insufficient to secure permanent footing for some new coinage, whose classical parentage is quite unimpeachable and whose grammatical attire forbids criticism. Very often does our language illustrate the truth of the old saying, "the first shall be last, and the last shall be first." It is a democratic institution, having adopted a declaration of independence against King Grammar and his whole court.

2. *Hybrid Words.*—English has no morbid fear of joining its words together regardless of the remoter origin of the newly-wedded elements. It is a language in possession of those who use it, and not one in perpetual and cringing serfdom to grammarians and lexicographers. It shows its genius in its independence of these linguistic tyrants, being

the most untrammeled and democratic tongue ever linked to an advanced and progressive type of human culture. When the term *sociology* was first introduced, narrow-minded classicists and other would-be guardians of the purity of the language objected that, since it was not composed of two Greek or of two Latin elements, but happened to be made up of one part Latin and one part Greek, it could not be admitted into the vocabularly of modern English. But how many "pure" words have filled forgotten graves since it was born! And this is but one example of the attempts to make the classical tail wag the English dog. Did English tolerate no hybrids, we should be without *Christmas, dislike, grateful, pastime, becalm, dishearten,* and many more of our common words. And where were the "purists" and the classicists when, in response to the needs of the political or the scientific moments, as the case might be, *anti-Tammany, near-genius, re-tattooing, pre-totemic, pseudo-mugwump, semi-taboo* and other interesting terms came into being? Hybridity is no efficient scarecrow for such a tongue as modern English. A fair field and no favor is now the law of survival and entries are welcome from all sources, known or unknown. The satisfying term that appears at the psycholgical moment has to undergo no *recherche de paternité.* English possesses some most remarkable hybrids—an example or two must suffice, here.

a. Remacadamizing.—In English one may speak of "remacadamizing" the road or, using the word as a noun, of its "remacadamizing." It is certain that no other language in the world can boast a word of such mixed and varied hybridity. *Remacadamizing* resolves itself into the following components: (1) *re-,* a Latin prefix, signifying "a repetition, or doing over again"; (2) *mac,* a Gaelic word for "son," in common use as a prefix for genealogical purposes; (3) *Adam,* the representative in a number of European languages (including Gaelic and English) of the Hebrew name of the first man, according to the Mosaic account of the creation as given in the first book of our Bible; (4) *-iz* (or *-ize*), the modern English representative, through French *-iser,* of the Greek verbal terminal -ιζειν; (5) *-ing,* the English suffix of the participle present, verbal noun, etc. The word *remacadamizing* thus represents five languages: Latin, Gaelic, Hebrew, Greek and English. The "root" (*macadam*) of this word exhibits also in another way the vitality of our English speech and its ability to draft new words into its vocabulary, whenever the need arises. The term *macadam* is really the family name of the man, *John Macadam,* who, in 1819, devised the well-known method of paving roads with small broken stones, etc. Celtic and Semitic had already combined to produce *Macadam,* "son of Adam," which the English language then took up and further molded to suit its genius.

b. Siouan.—When the late Major J. W. Powell, the anthropologist,

in the last quarter of the nineteenth century, drew up his classic list of the linguistic families of American Indians north of Mexico, he adopted as a suffix for each stock-name the convenient *-an.* One of the families thus constituted was the *Siouan,* embracing all the tribes cognate with those already known as *Sioux* or Dakota, etc. Now *Sioux* is in English a loan-word from Canadian-French, being really a "reduction" or abbreviation of *Nadowessioux,* which is found in varying spellings in the latter part of the seventeenth and during the eighteenth century in the writings of travelers, etc., of French nationality or extraction. *Nadowessioux,* itself, is a corruption of *Natoweisiw,* literally, "he is a small rattlesnake" (of the massassauga variety), a term applied, in the sense of "enemy" to Indians of the Siouan stock by their Algonkian neighbors, such as the Crees, Ojibwa, etc. The word *Siouan* turns out thus to be a very curious hybrid, to the formation of which the Cree-Ojibwa, French and English languages have contributed. *Natoweisiw* is composed of *natowé,* "snake," and the compound suffix *-is-iw,* which serves to give the word its special meaning. In Canadian-French the termination was corrupted into *-ssioux,* since the word was conceived of as a plural and given the sign of the plural in French *-x.* By and by the word *Sioux* appears as the representative of the longer term *Nadowessioux,* and so made its way into English, where also it was regarded as a plural. The word *Siouan* exemplifies, in a different way from *remacadamizing,* but quite as interestingly and just as remarkably, the genius of the English language in the evolution of hybrids. This characteristic, like its readiness to adopt foreign terms, is aiding English more and more in its candidacy as a world-language.

3. *Prefix and Suffix.*—There exist in the world languages that use prefixes only, others that know only suffixes; and there are also many that employ both these morphological devices. Few, like modern English, are free to use the very same particle as both prefix and suffix. And it is one of the complaints of foreigners that expressions of the type of "set up" and "up set" are often very far from being identical in meaning—indeed, may have no kinship in signification whatever. But this fact is a character of strength rather than of weakness, in a language such as ours. We can say: *aftermath* and *day-after; afore-time* and *pinafore; overalls* and *allover; overdo* and *do over; overlook* and *look over; overpay* and *pay over; overtake* and *take over; overwork* and *work over; inset* and *set in; intake* and *take in; instep* and *step in; onset* and *set on; outlay* and *layout; outlook* and *lookout; outworks* and *work out; by-gone* and *passer-by; undergo* and *go under; understand* and *stand under; uphold* and *hold up; upstart* and *start up,* etc. A study of the meanings of the words just cited will demonstrate that English has still a fertile field in this direction. It has been pointed out by the

cynically minded that *uphold* and *hold up* (in the colloquial sense of robbing on the highway) are just about opposite in their significations. A similar perversity of meaning attaches to the suffix use in such expressions, in colloquial use, as *take in, do up,* and some others. But it is such flexibility, nevertheless, that gives the language a powerful advantage over all other modern or ancient forms of speech. In English, too, a prefix or a suffix can, upon occasion, become an independent word. Thus we may speak of "isms" and "ologies"; and of "ana," derived from the termination of Shakespeariana, etc.

4. *"Reduced" Words.*—Another noteworthy characteristic of modern English is its capacity to "reduce" words of inordinate or unnecessary length—a sort of evolutional monosyllabism, as it were, in many cases. The *phone* and *bike* of the street to-day are kin of the dictionary terms *cab* (for French *cabriolet*) and *mob* (for Latin *mobile vulgus*), *bus* (for *omnibus*), etc. In America *Jap,* for *Japanese,* seems common to newspaperdom and occurs sometimes elsewhere. Slang and the special jargons of classes, professions, etc., of course, count such "reduced" words by the score. One place where the process is clearly seen at work is in the case of words and place-names adopted from American Indian languages. Thus, if Dr. J. H. Trumbull be right, the Algonkian *toboggan* has, by way of *Tom pung,* produced *pung,* the name of a well-known vehicle in New England; and the Indian *Quaquanantuck* in Long Island has been "reduced" to *Quag; Sagaponack* to *Sag,* etc. More than one "*Hog* Island" on the New England coast is perhaps all that represents, by way of *quahog,* the Indian word seen in the Narragansett name of the round or hard clam, *poquauhock.* Other "reductions" of words of Indian origin are: *Cisco* or *sisco,* which is all that is left of the Ojibwa name of this fish of the Great Lakes, *pemitewiskawet,* corrupted by way of Canadian-French; *longe,* or *lunge,* from Ojibwa *maskinonge*—the longer term being also in use; *coon,* via *raccoon,* from a Virginian Indian *arakunem,* or as Captain John Smith spelled it, *aroughcoun;* etc. In most of these cases the "reduction" has occurred at the beginning of the original word. Examples of "reduction" in which the terminal part in more or less mutilated form has survived are: *Squash,* which represents the Narragansett *askutasquash,* the name of this vegetable, of which we meet also another early form, *squontersquash,* keeping nearer the original; *hickory,* from the *pawcohiccora* (as the old writers give it) of the Virginian Indians. It sometimes has happened that in one part of the country the first part of an Indian word has survived in "reduction," and in another the last. The Narragansett-Massachusetts *scuppaug* has produced in Rhode Island, etc., *scup,* and in some other places, perhaps *pogie* or *paugie;* and *poquauhock* has given in Nantucket, etc., *pooquaw,* and elsewhere *quahog, cohog,* or even *hog.* Some of the words in our English dic-

tionary, concerning whose etymology little or nothing is known, may have originated in somewhat similar fashion. The "back-formations" of Dr. Murray, the English lexicographer, cited by Jespersen as one of the means the language employs for the purpose of forming new words "by subtracting something from old ones," belong under the head of "reduction." In this way *darkle* is derived from *darkling; pup* from *puppy; cad* from *cadet* or *caddie; grovel* from *groveling; difficult* from *difficulty,* etc. It is evident that the "back-formation" variety of "reduction" may be of great service in the future development of our language, being another aid in the process of survival as a world-tongue. A very recent addition to the vocabulary of to-day is "to *typewrite*," from *typewriter*—in England "to *type*" is much in vogue, a word which illustrates admirably the process in question.

THE OLD ACADEMY OF SCIENCE, PARIS. 1699–1793

II

By Dr. EDWARD F. WILLIAMS

CHICAGO, ILL.

IN his account of the Old Academy of Science M. Maury expresses the opinion that the history of the development of science in connection with the Old Academy of Science should be read and studied as a chapter in the development of mind, a chapter as important and as interesting as any chapter in the political history of the century. It traces contests in the search for truth. Of hardly less importance in the history of literature is the work done by the two academies of Science and of Inscriptions than that done by the French Academy itself, devoted as that is to literature alone.

The Academy of Science was reorganized in the last year of the seventeenth century by Ponchartrain, minister of state, and put under the control of his nephew, the Abbé Bignon, a man well fitted for the position he was chosen to fill. The decree of reorganization was signed at Versailles on January 26, 1699, and read to the academy on February 4. A change was made in the number and character of the members. Henceforth there were to be four classes of members: active, or pensionary, who were to reside in Paris and give their time to the study of science; honorary members who might be either foreigners or natives of France; associate members; and pupils, young men of promise who were admitted to the academy as students and helpers of its active members with the expectation that some time they would be received into the academy. Under the new arrangement all branches of science were represented. Larger and better rooms than had been occupied, rooms in the Louvre which the King himself had occupied, were set apart for the use of the academy.

A public meeting in honor of the reorganization was held on June 2, 1699. Fontenelle had taken the place of Duhamel, who had held the position of secretary from the establishment of the academy by Colbert in 1666. Fontenelle's eulogies, read at each annual meeting for a third of a century, are a history of the academy in the lives and work of its members. They are famous alike in the annals of science and of literature. The academy had a president, a vice-president, a director, and a sub-secretary, as well as a perpetual secretary. The director and his assistant were selected from the active members of the academy, the

president and vice-president from the honorary members. They were to represent the king, who nominated them and approved or disapproved all elections. These high officials were all of noble blood.

In the reorganization of the academy the names of men who had failed to attend its meetings with regularity or to show any real interest in its work were dropped, but old men who were still active were retained in spite of their conservative tendencies. The academy at once put itself into communication with scientific societies in the provinces, and also with academies in other countries in which the problems of physics, astronomy, mathematics and chemistry were studied. Personal relations were established between the astronomer Cassini of Paris and astronomers in England, Holland and Italy. Much attention was given to experiment, and special efforts were made to widen the horizon of observation by travel. Expeditions were equipped and sent out to various parts of the world at the king's expense.

In spite of the conservatism of the academy and discussions which lasted half a century the opinions of Newton in physics were finally accepted and those of Descartes rejected. Discussions over the calculus lasted more than five years. The theories of Newton were received in Holland, at St. Petersburg, and in many parts of Germany before they were current in either England or France. In 1726 the academy crowned a work by Père Mazieres of the Oratory which proved beyond a doubt the existence of the vortices of Descartes! In 1730 Jean Bernouilli published a volume on the same side and in 1736 Cassini de Fleury sought to harmonize the theory of vortices with Kepler's Laws. Fontenelle joined in the effort and was supported by two learned societies in Paris. Le Beau, of the Academy of Inscriptions, spoke jestingly of Fontenelle and Camille Falconyet, as "two old men besieged in a fortress formed of the vortices of Descartes in which they were defending themselves against the attacks of impetuous youth." The final blow against Cartesianism was struck by Buffon in 1747, although the way for the acceptance of the teachings of Newton had been prepared by Cardinal de Polignac.

Notwithstanding the fact that the academy was organized and sustained for purposes of investigation and in order to increase knowledge, and the further fact that its members above all other men were expected to favor and defend new views, it is not unnatural that conservative opinions should prevail. Some who were in the academy cared little for science in the true meaning of the word. Some favored those branches of study in which they were personally interested and had little interest in what was done in other branches. The Church defended the old views. It was opposed to any opinions which might lead to a change in methods of teaching. In the middle of the century France was behind countries like England, Holland and Germany in its knowledge of astronomy, geometry, physics and medicine. True such men as

Clairaut and Réaumer were leaders in the academy from 1700 to 1750, but Clairaut can not be put by the side of Newton in mathematics, or even of Leibniz, nor, eminent as he was, had he the creative mind of Bernouilli. Yet he was not without honor in other countries as well as in his own. In 1750 his Lunar Tables were crowned by the Academy of St. Petersburg. Réaumer, a many-sided man, carried physics to the heights where Buffon and Cuvier found them. Yet during the first half of the century the academy was unable to point to many men of the first rank among its members. Nearly all of them were men of ability, eager in the pursuit of knowledge, but wanting in those peculiar gifts which belong to men like Newton, or Descartes, or Leibniz. Yet the academy did a vast deal of excellent work. Problems relating to the sun, the moon and the earth were carefully and patiently studied. Newton's theories were shown by D'Alembert to be true, Bradley's discovery of aberration of the stars was made more valuable by measuring that of the planets and of the sun, and by estimating the amount of attraction on the earth. Thury discussed the figure of the earth. Thus, as M. Maury says, "a sort of propylea was formed for the Mécanique celeste of La Place." If Clairaut lacked somewhat in intellectual domination on account of the gruffness of his manners and his love of solitude, in all these respects Réaumer was his opposite. At his reception into the academy he read a paper on gravity, but he devoted his life to the study of the problems of physics. Dissatisfied with the Florence thermometer then in general use, he invented one which met the needs of the time. He made important discoveries in zoology, and wrote a fine history of insects. In practical affairs he was useful in improving the methods employed in the manufacture of pottery, and to his suggestions the iron industry owes a great deal. It is not surprising that with his attractive manners, his genial disposition, he should rule the academy for a score of years, and that he and Clairaut should be universally regarded as its two greatest men, whose fame was eclipsed in later years only by D'Alembert and Buffon.

New sciences like embryology gradually appear, and the sphere of those already studied is largely widened. De Lagny, who died in 1733, made important contributions to geometry and trigonometry, Nicole to the calculus of infinite distances. Joseph Saurin, 24 years older than Nicole, a Cartesian in physics but a Newtonian in mathematics, was also eminent for his knowledge of geometry. Carré published the differential calculus of Marquis de l'Hôpital, and Varignon, Fontaine and Clairaut improved and rendered more valuable the discoveries of Leibniz and Newton. The differential calculus we owe, so it is asserted, to the two Bernouillis, Joseph and Jean. During the period from 1699 to 1750 the academy was an important aid to mechanics, and it made large contributions to the knowledge of astronomy and geometry. In the first quarter of the century Dominique Cassini by his published

writings, and especially by his theories of the satellites of Jupiter and Saturn and his determination of their periods, brought the academy no little honor. The discovery of periodic stars in Hydra in 1704, by Joseph Maraldi, a nephew of D'Cassini, made an epoch in the scientific world. Through the influence of the academy astronomers in different parts of Europe were induced to study phenomena which as yet few had observed and none had explained. Brodiger's proposed explanations of the parhelia and the halos of the moon were deemed worthy of study at Greenwich and many other observatories. Bouguer in the Cordilleras saw aureoles surrounding his own shadow. After protracted and unsatisfactory discussions the academy decided to send an expedition to the pole and to the equator to measure the length of the meridian and determine the exact figure of the earth. La Condamine, accompanied by Bouguer and Godin, a young astronomer, not yet known to science, were sent to Peru in 1735. Maupertuis, Clairaut, Camus and Lamonier went to Lapland. At the suggestion of the minister, Maurepas, the expenses of the expeditions were paid out of the royal treasury. These expeditions and the increased knowledge which they obtained added very much to the scientific reputation of France as well as to that of the academy.

Yet disputes in the academy continued. Men like Maupertuis felt that their knowledge and reputation gave them the privilege of directing others. But men like Bouguer and Condamine resented the proffered instruction even of savants so distinguished as Clairaut and Maupertuis. These disagreements did not, however, prevent the academy from continuing steadily at its work. The journeys to the pole and the equator had furnished data from which it was shown that the earth is a flattened spheroid, though a century later Svanberg, a Swede, discovered errors in the calculations by which it had been made too flat. Condamine had taken with him as helpers an engineer, a horologist, a designer, and Joseph de Jussieu, destined to become famous as a botanist. Condamine was not satisfied with doing that for which he had been sent, and at his own expense and with great risk explored the Amazon. On this expedition he lost his thumbs and his ears. In 1738 he made quinine known to the world. Although not receiving the honor at home which he deserved, he has been called the Alexander von Humboldt of his time.

In 1749 an expedition was sent out to determine the moon's parallax. Efforts had been put forth in this direction as early as 1714. Observations at Berlin and the Cape of Good Hope had not been satisfactory. To secure better results Lacaille went to the Cape, Lalande to Berlin, Brody to Greenwich, Zandetti to Bologna, Wargentin to Stockholm, while Cassini de Thury remained in Paris. It was suggested that the phenomena to be studied should be observed at the same time at these different points. This friendship of scientists was better for the world,

many said, than the peace of Aix-la-Chapelle. Through the observations thus made errors were corrected and an impulse given to the study of astronomy which accounts in great part for the progress it made during the last half of the century.

Prior to the middle of the century little progress had been made in many of the sciences which in the next century engaged the attention of its foremost men. Sauvier had distinguished seven laws of sound and interested a good many men in their study. But at the beginning of the century the subject of acoustics was little understood and progress in its development was slow. Considerable attention was given to the subject of electricity, but neither Buffon nor D'Alembert believed that the calculus could be employed in this branch of science as it had been in setting forth the principles of astronomy and optics. A generation later than Buffon it was found that the calculus was of inestimable value in the study of every branch of science. Increase in the knowledge of chemistry was due quite as much to the pharmacists as to its special representatives in the academy. The contributions of one of these pharmacists, Etienne Geoffroy, in his tables of "Chemical Affinities" were of great value. Yet he did not realize, as Newton had done, the importance of his discoveries. As long as the influence of Descartes continued dominant in the academy, progress was difficult. Cartesians were content to explain the reciprocal action of molecules by mechanical forces. Such men as Nicolas Lemery and Fontenelle could see nothing but originality and useless knowledge in the discoveries of Geoffroy. They were unwilling to accept Newton's theory of gravitation. It was a long time before the principles accepted in England, or in Germany under the leadership of Stahl, in chemistry, prevailed in France. Up to the year 1780 the science of mineralogy in France was in a state of torpor. At that time the science of crystallography, and of geology, was unknown. Some progress had been made in the study of botany. As early as 1746 Guellard tried to persuade the academy to give its attention to the study of flora and fauna. The establishment of the Royal Gardens, chiefly for the benefit of medical science, had rendered the study of botany possible and attractive. In 1700 Tournefort, who had been at the head of the gardens since 1683, published his very important "Institutio rei herbariæ." His classification was based on color rather than on structure or function. The relation between descriptive and vegetable physiology was then unknown and was made of no practical value till a century later. Yet Tournefort recognized the existence of genera if not of species. In 1727 the existence of sex in plants was discovered. Not long after Tournefort's death Linnæus visited France, where he was warmly received and urged to remain as a member of the academy. Though refusing to leave Sweden permanently, he interested members of the academy in his theories and methods of classification which were at once seen to be an immense improvement

on those in ordinary use. Yet his methods were soon supplanted by those of the Jussieus.

There was a widespread feeling that the studies of the academy ought to be made of practical value to the people at large. For this reason Duhamel du Monceau, though abstract and severe in his methods of study, sought to use his knowledge for the benefit of agriculture and other industries. He improved the cereals of France, improved, if he did not introduce, the cultivation of the potato, discovered and taught the use of fertilizers, made forestry a science and published a treatise upon it which became a classic. Absence in England prevented his appointment as director of the Royal Gardens. This position was given to du Fay. Before the century was ended Buffon had grasped and proclaimed the unity of all branches of science. There was a growing interest during the last half of the century in zoology. Réaumur gave a great deal of attention to measures for increasing the collections in the museums, and studied the nature and habits of insects so thoroughly that he began, though he did not live to complete it, a six-volume work entitled "Mémoires pour servir à l'histoire des insectes." Of this work Buffon and many others made constant use. Buffon confessed his indebtedness also to the "History of Birds" written by Brisson, a physician and member of the academy. As representing the knowledge of ornithology at the date of its publication, about 1750, this work may be profitably consulted even now. In this branch of knowledge France was behind Sweden, Germany and England. Du Fay and Maupertuis were interested in the study of animals, especially salamanders and scorpions, yet this study was regarded by them only as a byplay. There was at the middle of the century only a single conchologist in France, Dezallier d'Argenville, and he was not in the academy. His book is still consulted. Laurent Jablot is said to have been the first man to study polyps and infusoria. As early as 1718 he anticipated not a few of the discoveries published to the world in 1740 by de Trembly of Geneva. Prior to the time of Réaumur polyps had been classed with vegetables. Anatomy and physiology were studied chiefly with reference to the science of healing. In the previous century men had been interested in these branches of study, some of them for their own sake independent of their relation to medicine. At the beginning of the eighteenth century Jean Méry, Joseph Guichard and Alexis Littré represented these subjects in the academy. Méry entered the academy about the time that Harvey made his discovery of the circulation of the blood, a theory the academy was slow to accept. Méry believed that in the embryo the blood circulates through the lungs. This theory was denied by J. G. Duverney, who gave special attention to the study of the glands and their relation to the urine and the brain. His papers were the subject of long and earnest debate. The problem

of generation was also a subject of discussion. There were two parties in the academy, the ovists and the spermatists, and the differences between them were not removed for a century and a half, or till it was discovered that fertilization is through contact. François du Petit, one of the physicians in the academy, devoted himself to the study of the brain and the eye. He was an anatomist from the cradle. It was a common saying that he listened to the lectures of Littré when he was only seven years old, and was able to prepare bodies for dissection at the age of nine. He was a man of vast knowledge and acquired great fame. Antoine Ferrein entered the academy in 1741. He advocated the theory that the circulation of blood is controlled by the heart. Winslow, a pupil of Duverney and unsurpassed as an anatomist save by Albinus of Leiden fifteen years his junior, confined his attention to the outside of the body, to monstrosities and to the dangers arising from certain kinds of dress. Discussions and differences in the academy increased and grew warmer with every addition to scientific knowledge, for the ability to harmonize the discoveries which were made nearly every year with what was already known seemed to be entirely lacking. Men had not yet learned how to compare one science with another. The study of comparative anatomy was in its infancy. Of paleontology almost nothing was known. This science did not receive attention in France till after 1725 when A. de Jussieu read his paper in the academy on the imprints of fauna and flora on certain rocks. These imprints he refused to consider and treat as whims of nature. De Maillet did not dare at this time to have his book on geology printed in France. It was not till Buffon's "Essay on the Epochs of Nature" appeared that men were willing to study nature from what was then called the modern point of view. Prior to 1740 the teachings of the church as to the origin of the earth were everywhere accepted. The entrance of philosophy into the academy added interest to its discussions. There were sharp differences of opinion as to what were living and what were dead forces. Leibniz had affirmed, Voltaire had denied, that the measure of force is as its mass multiplied by the square of its velocity. In this discussion Voltaire and Maupertuis took part. Every change in motion, said the latter, is brought about by the employment of the least possible amount of active force. The theory was attacked in the Berlin Academy by Samuel Koenig, with whom Maupertuis quarreled, and, although he was sustained in his contentions by the academy, it is now generally admitted that Koenig was justified in his criticisms. From the results of this quarrel Maupertuis never recovered.

As the discussions in the academy increased in intensity, and apparently in importance, public interest in its opinions increased also. In science its decisions were received as authoritative. Prior to the revolution not much attention was given to scientific studies in the schools,

but inasmuch as the members of the academy had received the best education, both in science and in philosophy, which France could furnish, it was entirely natural that the common people should accept their opinions without hesitation. The members of the academy lived simply, gave their time to their favorite pursuits, and through their publications had large influence on the civilization of France and even of Europe. The work of the academy through the century was directed by a few able men. Fontenelle, who succeeded Duhamel, the first secretary, felt the burdens of his position as early as 1730 and offered his resignation, which was not accepted till 1740. He was at that time eighty years old and his successor, Mairan, eminent for his attainments, was nearly as old. He was soon followed by Grandjean de Fouchy who had won fame as an astronomer, who retained his secretaryship for thirty years. Condorcet was his assistant, but the real control of the academy was in the hands of Buffon. Yet Buffon was unable to prevent Condorcet from succeeding de Fouchy.

At the death of Buffon there were other naturalists who were well prepared to take up his work and carry it forward even more successfully than he. They were less prejudiced than he against new opinions. Some of them could give more accurate descriptions of natural objects. Buffon's knowledge of science prior to the century and in a good degree up to his own time was extensive. It was not accurate like that of the Jussieus and of Lavoisier. He did little for the future save through his suggestions and his wide generalizations. He derived living beings from molecules, and the atoms in which Epicurus believed. But he did not solve the problem of generation. As an administrator he had few equals. His gift for order and arrangement was very great. He made the Garden of Plants a great help for students of science. Yet in most departments of science, England during Buffon's life was fifty years in advance of France. Yet the academicians were by no means idle, nor did they fail to appreciate the discoveries of their contemporaries in other countries. Men like Daubenton gave lectures in connection with the Royal Gardens and were on the lookout for young men to take the place of their elders in the academy. In his investigations he just missed having a share in making comparative anatomy a real science. Vicq d'Azyr, of Normandy, a pupil of Antoine Petit, carried the study of zoological anatomy to a great height. Buffon would gladly have seen him director of the Royal Gardens, but Daubenton took care to place him where his gifts as an anatomist would have full exercise. He was a member of the academy in 1774. His reputation rests on his work on anatomy and physiology published in 1786. Two years later, at the death of Buffon, he became his successor. He was the precursor of Cuvier. He was one of the first to point out the importance of the teeth in the study of animals.

The conservatism of the academy is shown in various ways, but

perhaps in nothing more clearly than in its willingness to reject inoculation as a protection against the ravages of the smallpox. In 1764 it was on the point of condemning it altogether, but was prevented from doing so by Petit, who was more reasonable than some of his associates. A few years later Jenner was made an associate member of the academy. Bailly's report, which appears in the *Mémoires* for 1784, carried the day for inoculation. Inoculation was favored by at least two of the king's ministers, Turgot and Malesherbes. About this time Mesmer was in Paris and by his lectures and experiments created much excitement. The academy appointed a committee of which Dr. Franklin, then a resident of Paris as a representative of the United States, was a member, to visit Mesmer, but Mesmer refused to impart his secrets to him or to any one outside his chosen circle. Although de Jussieu was favorably inclined toward Mesmer and his methods, Lavoissier, Bailly and Franklin reported against him. In spite of the opposition of the academy, Mesmer prospered, though his theories were not widely propagated during the Revolution. Subsequently mesmerism was opposed as a species of somnambulism. The academy was called upon to find a remedy against the bite of mad dogs but was unable to do so. The sufferings of the people during the later years of Louis XVI. drew the attention of the academy away from the study of science to the consideration of means for helping the people. The price of bread had risen to such a height that the academy was asked to consider its cause and to see what could be done to bring it back to the former figures. A wise report, showing that the price depended always upon the price of cereals, made by Leroy, Desmourets, and Tillet did something to calm public feeling. In 1782 the aid of the academy was asked by the States Assembly to help in determining the proper values of land. Through the impulse given by the Montyon prizes, offered as early as 1779, some successful efforts were made to protect the lives of men whose work exposed them to unhealthy conditions. In 1784–5 a work on metals by Henri Albert Josse, of Geneva, received the approval of the academy.

The academy, though careful not to express itself on any political question, did not escape suspicion during the terrible days of the Revolution. Some of its members, Bailly and Lavoisier, perished on the scaffold. Condorcet committed suicide. The lives of others, Malherbes, Bochardt and Saron were undoubtedly shortened by the strain of the period. Yet the new government strove for a time to make use of the knowledge of its members. They were asked to draw up and present to the Assembly a system of weights and measures, as well as of money, which would meet the demands of the new era. The first committee was composed of men like Lavoisier, Lagrange, Borda, Condorcet and Tillet. The request was repeated in 1792 and was referred to a committee composed of Lagrange, Berthollet, and Antoine Manges, of the Academy of Inscriptions. This committee reported in favor of

the decimal system which was afterwards adopted. Meanwhile the work of the academy was supposed to go on without interruption. But its sessions could not be held regularly. Some feared to attend them. Bailly and Condorcet did not venture to show themselves at these meetings. Yet Lagrange, Laplace, de Jussieu, Desfontaines, Adamson, Haüy, Berthollet, Coulomb, Borda, Bossuet, Portal, Thomasin, Daubenton and Lavoisier were usually in their places at every session of the academy. Lalande acted as secretary. November 14, 1792, Chanfort moved that the sessions of the academy be suspended. This motion did not carry, though a similar motion passed November 26. The last meeting, however, was held December 21, at which it was voted to adjourn for Christmas. Although the academy did not meet as an academy, the ministers of the government continued to ask its advice as late as January, 1793. A Commission of Public Instruction sought its opinion as to a system of weights and measures. The opinion was given by Borda, Laplace, and Lagrange. The report which these men made is the last report which appears on the records of the Old Academy. Yet many of its members wrought as patriots for their country. Fourcroy discovered a new method for making saltpeter, Guylonde, Morceau and Berthollet worked on steel, Monge gave his attention to improving the foundries, and A. C. Perrier to forges. August 6, 1793, the Convention sent to the academy, which it suppressed August 8, a request for its opinion as to the value of money. August 14, 1793, Lakenal, as one of the officers of the new government, issued a decree requiring the members of the academy to meet in their old place and be ready to answer any question which might be sent them. But these meetings were irregular and of little value. The academy had been proscribed as the enemy of the Republic. During the four years from 1789 to 1793 half of the members of the Old Academy died. Many of them had lived in poverty, all of them in fear. October 25, 1793, the Convention ordered the establishment of the *Institut,* of which the Academy of Science might form one of its classes. It was indeed its first class. It was intended to serve the Republic by its practical knowledge of mathematics and physics. Nothing was done at this time toward establishing an Academy of Moral and Political Science, or of Literature and the Fine Arts. These were to come later. This order, which was secured through the influence of Lakenal, was, as a matter of fact, carrying out the order of the king as issued April 23, 1783. All science was united in two great classes, physical and mathematical. By the Republic these classes were made sections of the *Institut.* In each of these sections there were three *pensionaires,* and three associates. In 1803 another reorganization took place and in the new *Institut,* the Academy of Science was given the third place. Its further history is the history of a section of the French Institute.

HISTORY OF GOLD MINING IN THE UNITED STATES

By Professor R. A. F. PENROSE, Jr.

PHILADELPHIA, PA.

Period from 1800–1848

GOLD was known by the Indians to exist in the United States long before the white people discovered it, but unlike the Indians of Mexico, the more northern natives did not make elaborate use of it, and it did not seriously attract the attention of the settlers until shortly before the beginning of the nineteenth century. No very important mining, however, was done until after 1800, when a little gold began to be obtained in North Carolina. Long before that time the gold of California had also been known to the natives and to the Franciscan monks, but that country then belonged to Mexico and was not taken by the United States until 1846.

The first important gold mining, therefore, in the United States was in North Carolina, when shortly after 1800 the auriferous gravels of Cabarrus and Montgomery counties were worked in a small way. From that time until 1827 small quantities of gold were produced in these and other parts of North Carolina, though not enough to cause much excitement; but the discoveries then spread into the adjoining states, and in the next two or three years South Carolina, Georgia and Virginia began to produce important quantities of gold, while Alabama and Tennessee also soon began to supply a small amount. In the meantime gold-bearing veins had been discovered in addition to the gravels, and from the two sources the production of gold grew considerably. A great excitement followed and many thousands of people rushed to the gold diggings.

Later discoveries extended the area in which gold was found until it had been traced from Alabama northeastward to the Canadian border, but very little was discovered beyond Virginia. The gold deposits characterize certain geologic horizons which flank the east slope of the Appalachian Mountains, and the most productive part of this belt has so far proved to be in western North Carolina, the adjoining part of South Carolina and northern Georgia, while Virginia and Alabama have been smaller producers and Tennessee has supplied a little. In the states north of Virginia small quantities of gold have occasionally been found, but not enough to be of much commercial importance,[1]

[1] Exception to this must be made where small quantities of gold are produced as a by-product from copper ores in Tennessee, Maryland and New Hampshire, and from iron ores at Lebanon, Pennsylvania.

while to the south, the gold formation, after passing through part of Alabama, disappears under the younger formations of the lower Mississippi Valley.

The annual production in the southern states never reached much over $1,000,000, and up to 1847 the total had been $24,537,000.[2] After that time the production fell off considerably, and though it rose later under the general stimulus to gold mining caused by the California discoveries, it soon fell again. Mining still continues, however, to the present day, and the production some years reaches several hundred thousand dollars, in others only a small part of this amount. The experience people had obtained in gold mining in the south and the fact that the production of that region was on the wane, caused them to be quickly attracted to new fields when the reports of the discoveries in California reached the east in 1848.

Period from 1848–1859

The gold of California was known long before 1848, but the knowledge concerning it was too vague to attract much attention. About 1769, when California was a remote Mexican province, the Franciscan monks began to establish missions along the coast for the conversion of the Indians, and gradually extended their influence over them, employing many in rural pursuits and trading with the others. The missions became the seats of government of prosperous communities, and the Indians from the outside, who came to trade for provisions and clothes, were observed to be always well provided with gold dust for this purpose. The monks thus became aware that an abundance of gold existed on the west slope of the Sierra Nevada, but they feared the effect such news would cause if it reached the outside world. They remembered the cruelties that had been practised by the early explorers of Mexico and South America in their mad rush for gold, how the land had been devastated, towns destroyed and whole tribes almost annihilated by the plunderers. They knew that there would be a rush to California if its wealth became known, and they feared that the man of their own day would be no more conscientious in his methods of securing gold than had been the man of the sixteenth century. They saw the possibility of their quiet settlements being disturbed and their power overthrown; hence they concealed their secret. In the meantime a little mining had been done from time to time by adventurous strangers who came that way, but the results were not sufficiently important to attract much attention, and the gold of California did not become generally known until it was discovered by Americans in their irresistible trend westward.

The discovery was made by James W. Marshall in the latter part of

[2] Report of the Director of the Mint, 1910.

January, 1848. Americans had begun coming into California several years previously and a colony was already established near where Sacramento now stands. Marshall was constructing a saw mill some forty miles distant on the west slope of the Sierra Nevada and on the south fork of the American River, which is a tributary of the Sacramento River. He observed some glistening particles in the gravel washed by the waters of the mill, and at once identified them as gold. A few days later he went down to the settlement on the Sacramento River to tell of his discovery to Colonel Sutter, with whom he was associated in the erection of the mill.

In spite of all efforts to keep the discovery from public notice the news spread; the people in the neighborhood made further search, and soon found gold to be abundant in many other places. The excitement rapidly increased, and by the summer of 1848 several thousand people were already mining in the neighborhood. San Francisco, then a small village, was almost depopulated in the sudden exodus for the gold fields. By autumn the news had reached the eastern states and foreign countries, and history has never before or since recorded such a mad rush of different races of people to a common center, overcoming difficulties that would have been considered almost insurmountable had it not been for the idea of gold, limitless gold, lying there in the ground to be dug up by the first who came. Among the earliest to arrive from the outside were Mexicans, Peruvians, Chileans and Chinese, as they could reach the region quickly by sea; but the great tide of immigration that soon came from the eastern states, around Cape Horn, across the Isthmus of Panama and over the emigrant trail, soon placed the Americans in the majority, and by the end of 1849, there were nearly 100,000 miners on the ground. Thousands of others died on the way, from exposure and starvation, from heat and thirst in the desert, from attacks by the Indians and from cholera, which killed many along the trail in 1849.

In the meantime one discovery of gold rapidly followed another in the gravels of the many rivers and creeks that run down the west slope of the Sierra Nevada, and miners were soon working for over 150 miles along the mountains. Since then the range of the gold discoveries has spread over wider limits, reaching from the northern to the southern boundary of the state, but the larger part has come from the region worked in the early days, extending from Mariposa County on the south to the Feather River on the north. Fortunes were made quickly and lost with equal facility, but in the meantime a new region was being developed with wonderful rapidity and the western progress of the United States had, as if by a single jump, been advanced over fifteen hundred miles, from the Missouri River to the Pacific Ocean. Throughout the world, the discoveries in California stimulated interest

in gold mining, and as a direct result the great Australian gold fields became known in 1851 and mining in the gold regions of the southern states was greatly stimulated. With all these notable results, it is pathetic to relate that Marshall, who discovered the California gold, and his associate Sutter, both died poor and disappointed men, many years later.

The first gold mining in California was done along the bars and banks of rivers and creeks, while later the whole streams were turned from their courses, and the gravel in their beds was washed for gold. The American, Yuba, Feather, Stanislaus, Tuolumne and other rivers, became famous as gold producers. The gravels in the dry ravines were also washed, and these were called "dry diggings" in distinction from the river, or "wet diggings." When the gravels in the lowlands began to show signs of exhaustion, the miners sought others higher up in the mountains, and there they found the old Tertiary deposits, known as "high gravels." In the meantime the gold-bearing quartz veins were discovered, and thus began the operation of many of the more lasting mining districts of California, such as Angels Camp, Chinese Camp, Amador City, Sonora, Grass Valley, Nevada City and many other places which made the great Mother Lode and other quartz lodes of the Pacific Coast famous.

In the early mining operations, gold had been obtained by digging the gravel by hand and washing in pans or in the devices known as cradles and sluices; but when the richer deposits were exhausted and lower grade gravels had to be worked, efforts were made to find means to mine on a larger and cheaper scale. The result was the introduction of what became known as hydraulic mining, a process invented in 1852 by Mr. Matteson, from Connecticut. This consisted in throwing a stream of water through an iron nozzle, called a monitor, under immense pressure, against a gravel bank. The gravel was thus torn down and washed through the sluices, where the gold was recovered. The method was so much more rapid than the old devices, that it was extensively introduced, and whole hills were washed away. In the meantime, however, the farming interests of California had become important, and the immense quantities of gravel and sand washed into the rivers by hydraulic mining filled the channels and caused floods, which devastated the lands. This difficulty became so serious that in later years a law was passed restricting hydraulic mining in places where the débris interfered with farming lands below. Still more recently the process of working gold-bearing gravels by dredging has been extensively introduced and has considerably increased the production.

The most productive era in California gold mining was from 1850 to 1859, when the average annual output was about $55,000,000, while

the year of greatest output was 1853, when almost $65,000,000[3] were produced. After 1859 the production fell off greatly, partly from the exhaustion of the richer placers, and partly because thousands of California miners left for the Comstock lode. In 1889 it had fallen to a little over $11,000,000,[4] but in more recent years it has risen again, and has ranged from about $16,000,000 to over $21,000,000 annually. The total production of gold in California from 1848 to 1910 has been over $1,500,000,000, or almost half of the total production of the United States to date.

Period from 1859–1890

While these events were going on in California, gold and silver were being discovered in many places in the Rocky Mountains and in the desert country between them and the Sierra Nevada, known as the Great Basin. Though these regions are nearer the eastern states than California, their mining resources were not developed until long after those of the latter. This was due to several causes: The mines of California had already been discovered while those of the interior were as yet unknown; many California pioneers came by sea and knew nothing of the interior, while those who came by the emigrant trail found the difficulties and dangers such that they felt fortunate when they crossed the Sierra Nevada and entered the fertile valleys and salubrious climate of the coast. They tarried, therefore, as little as possible in the Rocky Mountains and the Great Basin, but hurried on to where they knew gold existed and where they would be safe from dangers which had already lined the emigrant trail with the bones of thousands of people. Hence it was not until over ten years after the discovery of gold in California that important mining began to the eastward.

After the California placers had been shorn of their richest treasures, many men left them to seek new discoveries, spreading north and south along the coast, and eastward beyond the Sierra Nevada. The result was that many mines which have since become noted were found during that time. Among them the most celebrated was the Comstock lode, which was destined to produce more gold and silver than any other one lode that history had recorded, and the development of which was accompanied by the most sensational and dramatic series of events ever recorded in a mining camp.

The Comstock lode is situated on the slope of Mt. Davidson, just east of the main range of the Sierra Nevada, some twenty miles beyond the California border, in what is now Nevada, but what was then a part

[3] Report of the Director of the Mint, 1910.

[4] Charles G. Yale, California State Mining Bureau, Report State Mineralogist, 1896, p. 64.

of the Territory of Utah. It is just south of the emigrant trail over which many early explorers of California had passed, but the region was a dry, inhospitable desert, destitute of vegetation and inhabited only by a few half-starved Indians, so that the pioneers had given it but little attention. Shortly before the discovery of the Comstock, however, some placer gold was found in that vicinity and a small settlement started, which later became Carson City. In 1857 two brothers named Grosh discovered the Comstock lode itself, but they died shortly afterwards, and the next year it was worked in a small way by others. Large bodies of ore, however, were first found in 1859, and then the news of the discovery spread rapidly and a great rush of people commenced, among them Henry Comstock, for whom the lode was named. The town of Virginia City sprang up from the desert and became a flourishing community.

The Comstock lode is an immense vein about four miles in length and several hundred feet in width, enclosed in igneous rock. Its great size admitted the locating of numerous mines along its course, many of which later became famous, such as the Consolidated California and Virginia, the Yellow Jacket, Crown Point, Hale and Norcross, Ophir, Belcher, Chollar and many others. Virginia City was at that time more accessible from San Francisco than from any other city, and hence the latter place became the supply point for the wants of the Comstock mines. San Francisco capital and energy poured into the district; the Comstock mining stocks were listed and dealt in on the San Francisco exchange, and San Francisco grew rich with the Comstock's millions. The gold discoveries in California had given San Francisco its first boom and had raised it from an obscure village to an active, bustling seaport; the discovery of the Comstock advanced it still further to a great city and one of the most important seaports in the world.

Mining progressed at a rapid rate at Virginia City, the mines reached great depths, and the water and heat increased at an abnormally rapid rate. It was then that Adolph Sutro commenced the great tunnel which bears his name, with the object of draining the mines and making an easier outlet for the ore, but before the project was completed the great "bonanzas" were largely exhausted, and by 1880 the production of the district had greatly declined. For a long time after that, mining consisted mostly in going over the old workings and waste dumps where the haste of the early days had left many rich pickings, but in recent years some entirely new development work has been started, and some of the old mines have taken a new lease of life.

The ore of the Comstock lode carried both gold and silver, with silver in the preponderance. In the haste and excitement of early days, accurate records of production were often neglected, but the total output of the Comstock mines to date has probabaly been between $400,-

000,000 and $500,000,000, while some estimates are even higher. So great was the quantity of silver produced that the monetary ratio between gold and silver was disturbed, and the curtailment of the coinage of silver in several countries of America and Europe was brought on partly by the immense quantity of the metal suddenly thrown on the world from the Comstock mines.

In the meantime the Rocky Mountains had been receiving the long-delayed attention of the prospector, and in 1858 gold was found in Colorado, in the sands of Cherry Creek, a tributary of the South Platte River, where the present city of Denver soon grew up. Pioneers poured in from the east, and discoveries followed in rapid succession. In the following few years the mines of the Blackhawk, Central City, Golden, Breckenridge, Boulder and other districts were discovered. In 1859 the placer gold of California Gulch, near where Leadville now stands, was discovered, and the town of Oro City sprang up. The diggings were soon exhausted, however, and Oro City vanished, to be replaced a few years later by Leadville, which grew up after valuable silver ores were discovered in the same locality. Many of the early gold districts of Colorado continue to produce gold, and though some of them are not so much heard of now as are the later discoveries like Cripple Creek, yet they have added largely to the prosperity of the state.

In the meantime the report of the discovery of gold on Pikes Peak drew a vast multitude of people there in 1859, only to be disappointed in their search. Their numbers were greatly increased by many of those who suffered in the financial panic of 1857, and about 100,000 people are said to have sought the new region in the first year. Nothing of value was found on Pikes Peak, and many of the enthusiastic explorers, who had traveled thither in the wagons known as prairie schooners, bearing the inscription "Pikes Peak or Bust," went away with this changed to "Busted." Little did they dream in their disappointment that just west of Pikes Peak, on the small stream of Cripple Creek, were immensely rich gold deposits, that were to be discovered thirty-odd years later. Though the Pikes Peak episode was a failure, it had the effect of bringing a large number of people to Colorado, many of whom, instead of going home, started into the mountains and were the early explorers of mining camps throughout the west. The high and rugged character of the Rocky Mountains in Colorado impeded, though it could not altogether stop, the direct passage westward; in fact, so dangerous were some of the mountain trails that the expression that a man had "gone over the range" came to be applied to any one who had died, and is still heard among "old timers" in many parts of the Colorado Rockies. Hence the Colorado miner tended to spread to the south and north, while the Californians continued to spread along the Pacific coast and eastward into the desert. The two tides of exploration

rapidly invaded the interior country, and between 1860 and 1885 made many discoveries, the mining camps to the eastward becoming affiliated with Denver as a center, those to the westward having closer relations with San Francisco. Even to-day this distinction is observable.

After the discovery of the Comstock lode, Californians began to appreciate the possibilities of the desert and they rapidly overran that region, but even before the discovery of the Comstock they had begun to explore the region east of the Colorado River, then known as New Mexico, but later divided into New Mexico and Arizona. Here gold had been mined by the Mexicans long before the American conquest, and many of the old mines were reopened and new ones discovered by the American miners. As early as 1853, the old town of Tucson became an active mining center, and somewhat later the gold mines near Prescott, Phoenix, Santa Fé and many other places were developed. Between 1860 and 1864 the gold of the region now included in Idaho and Montana was discovered, and the Snake, Clearwater and Salmon River regions, the Boisé Basin, the Owyhee region, Deer Lodge, Bannack City, Alder Gulch, Helena and many other districts became important gold producers.

Though all these discoveries were of much local importance, no one of them was great enough to mark an epoch in the gold mining industry of the country, as was the case in the discovery of the gold of California and the Comstock. An exception to this, however, should be made in the case of the Boisé Basin and the surrounding country, from which many millions in gold were taken in a short time. Most of this gold, however, was sent to San Francisco, and in those early days, when people were too busy to keep very accurate records, a large part of it was credited to California mines; but those who know the Boisé region and the prosperous city of Boisé are familiar with the immense production that once came from there.

We now come to the discovery of gold in the Black Hills of South Dakota, a region somewhat removed from those we have been discussing. In 1874 General G. A. Custer, while on an exploring expedition there, reported gold in some of the stream beds. The following year miners began to come into the region and very soon a general rush for the new gold fields occurred. The Black Hills, however, were then a part of the Sioux Indian reservation, which was not open to settlers, and the various United States military posts were instructed to keep the people out; but in spite of this and the fierce opposition of the Indians, numerous exploring parties managed to reach there; and finally, in 1876, this mountainous region, which had long been looked on by the Indians as their last resort for safety, was thrown open to settlers. From that time until the present the Black Hills region has been a steady producer of much gold and some silver, the production of gold usually

amounting to several million dollars yearly, and aggregating, up to 1910, approximately $150,000,000. At the present time, the old placers have been largely exhausted, but the gold-bearing veins are extensively worked, especially at the celebrated Homestake Mine.

Effect of Discoveries of Silver on Gold Mining, 1859–1890

While the gold of the west was thus being found and poured into the mints and commerce of the world, numerous discoveries of silver ores, often of immense value, were being made in the Rocky Mountains and the Great Basin. The first great discovery of silver ore in the United States was that at the Comstock lode, but others followed rapidly, until the multitude of mines opened between 1860 and 1885, made the United States the greatest silver producer in the world. Silver was then valuable, the deposits were larger than had ever been known to exist before, and the profits were immense. Towns grew up based entirely on the silver industry, and silver was the chief topic of the thoughts, conversation and daily pursuit of the people; the prospector looked only for silver, and a class of people began to grow up who knew silver ores but not much about other ores, so that many gold deposits were passed over, to be discovered years later.

This condition of affairs had the effect of stimulating the silver industry to its greatest extent, almost to the total exclusion of the search for gold, and discovery after discovery of silver deposits in the Rocky Mountains and the Great Basin was the result. First came the Comstock lode in 1859, and then followed rapidly between the years 1860 and 1885 the Reese River, Eureka, White Pine, Pioche and the Calico districts in Nevada; the Park City, Little Cottonwood Cañon, Frisco and Tintic districts in Utah; the Leadville, Silver Cliff, Aspen, San Juan districts in Colorado; Butte City, Montana; Tombstone, Arizona; Silver City and Lake Valley, New Mexico; Coeur d'Alene, Idaho, and in more recent years, Creede and Tonopah. Many other regions of silver discoveries might be mentioned, but the above list shows the vastness that the industry had reached.

Effect of Depreciation of Silver on Gold Mining, 1875–1890

The enormous production of silver, accompanied by increasing outputs in Mexico and elsewhere, brought about the inevitable result and caused the fall in the value of the metal. At the time of the opening of the Comstock lode in 1859, the price of silver was $1.36 per ounce. Until then silver had been very scarce, and in spite of the enormous output of the Comstock and other mines discovered later, the price of the metal held up wonderfully until 1873, ranging in value from $1.36 to $1.29. The great flood of silver that was being produced, however, finally made itself felt, and slowly but surely the price fell. In the

meantime the governments of America and Europe, fearing that silver was becoming too common a metal, began to curtail its coinage; and this action still further depreciated its value.

Previous to this great output of silver the enormous quantity of gold from California and Australia had discredited the stability of the value of the latter metal, and silver was considered by many to be the safer of the two for coinage. In fact, Holland had actually adopted a silver standard for coinage in order to avoid the dangers of the depreciation of gold, but from the day the output of the western mines made people realize the possibility of an enormous production of silver, that metal fell into disrepute. In 1886 the price fell for the first time to less than $1 per ounce, and after that it continued downward, with occasionally slight fluctuations upward, until it went below 50 cents per ounce. In late years, with the curtailment of production, silver has risen somewhat and has ranged a few cents above fifty cents an ounce. At the present time most of the great mines that were once worked entirely or mostly for silver are closed, and the production of that metal in the United States, though still large, is derived principally from ores containing both gold and silver, and as a by-product from copper and lead ores, with a little from zinc ores.

With the closing of the silver mines many men were thrown out of employment, and thousands of them started into the mountains to find something more desirable to work than the discredited silver. The long-neglected search for gold attracted many of them, for in gold they saw a metal that was not falling in value day by day. The result was remarkable, and in an incredibly short time many new discoveries of gold began to be made.

Period from 1890–1911

The Cripple Creek district in Colorado was the most noted of the early gold discoveries following in the wake of the fall of silver, but so little confidence was put in it at first that those working there were scoffed at and called "alfalfa" miners by the old-time silver men; yet in a few years it was producing many millions annually and Colorado had risen to the foremost ranks as a gold producer. The gold of Cripple Creek was discovered in 1890 by Robert Womack, but was first actively worked in 1891 by E. C. Frisbee and E. M. De La Vergne; and in 1892 and 1893 the rush began which brought many thousands to this new El Dorado, where they hoped to recuperate fortunes lost in silver mining and in the financial panics of that time. The town of Cripple Creek suddenly sprang into existence high up on the mountains just west of Pikes Peak, and soon had a population of over 10,000 people, while the surrounding district contained several times that number. Many millions were produced yearly, and though the output is now less than

formerly, it is still large, and Cripple Creek possesses a record for gold production rarely equalled. The total production up to 1910 was over $200,000,000.

The gold of Cripple Creek occurs mostly in veins, though some small placer deposits were worked in the early days. Instead of one great vein as at the Comstock lode in Nevada, there are very many smaller veins, representing ore bodies formed in fissures in the choked-up neck of an old volcano. Erosion has altered the appearance of the volcanic vent, but the geological structure proves the origin of the region.

About the time of the discovery of the Cripple Creek district, new gold deposits were found at Leadville, in Colorado. We have seen that gold placers were worked in this region in 1859, but were soon exhausted, and that in 1874 silver-lead ores were discovered and again brought a boom to the region. With the fall of silver, Leadville had lost much of its prosperity, but again picked up on the discovery of gold ores shortly after 1890. About this time, and later, many mines in the San Juan region and elsewhere in southern Colorado also became important gold producers.

Following quickly in the train of the fall of silver, news came of the discoveries of gold in the Klondike region. The Treadwell and other mines in southern Alaska had long been worked, but in the far north mining had not been very active. More or less gold had been mined on the Yukon and its tributaries for many years, and from 1886 to 1895 interest was somewhat stimulated by discoveries on Forty-Mile Creek, Koyukuk River, Mission Creek, Mynook Creek, Tanana River and many other streams flowing into the Yukon; but the production was not very great and the industry was carried on in a desultory way. With the discovery, however, of gold on the Klondike River in 1896, this apparent apathy was turned to the wildest excitement.

The Klondike River is in the Yukon Territory of Canada and flows into the upper Yukon River east of the Alaska border. Gold was discovered there on August 17, 1896, and a stampede to the new district followed which will always be memorable for the hardships encountered and the frightful mortality among those who took part in it. By 1898 over 40,000 people were camped on the Yukon, at the mouth of the Klondike, while many had died on the way, frozen on the White Pass, or on the long winter trail from Edmonton, or starved in the forest, or drowned in the Yukon, or shipwrecked in the Pacific. Whole parties often perished and nothing was heard of them until perhaps years later their outfits were found on the wilderness trails. Dawson City came suddenly into existence on what a few months before had been a barren river bank, and took its place as the metropolis of the gold regions of Arctic America. Soon after the first discovery of the Klondike gold, the deposits on various smaller streams in the vicinity, such as Bonanza

Creek, Eldorado, Hunker, Gold Bottom, Dominion, Sulphur, Gold Run, Quartz and other creeks, were found.

The richest of the Klondike placers were exhausted in a few years, the production began to fall and people predicted the end of mining there, especially as no very important gold-bearing veins had as yet been discovered; but in recent years, with the introduction of more modern and economical appliances, the immense areas of low-grade gravels are being successfully worked, and the Klondike will probably be an active gold producer for many years to come.

In 1898, at the height of the Klondike excitement, gold was found at Cape Nome on the Alaska Coast of Behring Sea, north of the mouth of the Yukon. The first discoveries were made on Anvil Creek, a few miles back from the beach, and during the following year in the beach sands themselves. Again a stampede started to the north, and though not so many people went there as to Dawson City, yet the number was considerable, and large quantities of gold were quickly produced by those who were fortunate enough to escape shipwreck and other disasters on the way.

The result of these far-north gold discoveries was the exploration of that country many years before it would otherwise have taken place, and in a very short time the region, up until then little known, except in spots, became familiar to all. The whole of it has since been overrun by the prospector, and many other gold districts than those mentioned have been found, but the chief producers to-day are the Klondike, Cape Nome and the Fairbanks regions, the last being on the Tanana River, a tributary of the Yukon in Alaska. The production of Alaska in 1910 was estimated at $16,987,990, while that of the Yukon territory of Canada, which includes the Klondike, was estimated at $4,550,000, a decrease from the maximum of $22,275,000 in the boom year of 1900.[5]

The Goldfield district in Esmeralda County, Nevada, was another discovery that followed after the fall in price of silver, and here from 1902 to 1904, and later, were found great deposits of gold-bearing quartz that have made the region one of the most important gold districts of the world. The Goldfield Consolidated Company to-day is the largest single gold-producer in the United States, its output in the year ending October 31, 1910, being $10,866,752. The region is not far from the Comstock lode, and many an old prospector of the latter region doubtless trod over it without realizing the value of what was to be discovered over forty years later. Other districts in Nevada, such as Silver Peak, Rawhide, Bullfrog, Round Mountain, Delamar and many other places, also became important gold-mining centers; and Nevada,

[5] "Mineral Industry," New York, 1910, p. 266.

like Colorado, from being mostly a silver-mining state, has become a great gold producer.

In the same way, after the fall in silver, the mines of Fergus, Chouteau, Madison and other counties in Montana, assumed fresh activities; in Idaho the old gold regions of the Boisé Basin and other places in Boisé County, as well as in Owyhee and other counties, again attracted attention; in Utah the old gold mines at Mercur, in the Camp Floyd district and elsewhere were reopened; in Arizona some of the gold districts of early days, which had long been abandoned for silver mining, were reopened, while new discoveries were made in many places, especially from the Gila River northwestward to the Colorado River; in New Mexico several old districts were reopened and a few new ones discovered. In California there was a general revival of gold mining and the production materially increased. New discoveries were made in the northern part of the state, in Shasta, Trinity and other countries, and also in the barren regions of the southern part, where many districts were added to the list of producers. Oregon and Washington also felt the stimulus to gold mining, though the production from those states has never been large. Even the Philippine Islands have begun to produce some gold, and though the amount is yet small, it will probably increase.

Present Distribution of Gold Mining in the United States

The final result of the exploration for gold in the United States since 1800 is that the metal has been found in large quantities along the Pacific Coast from California to Alaska, also in the Great Basin region east of the Sierra Nevada, in the Rocky Mountains and in that eastern outlier of the Rocky Mountains known as the Black Hills; it has been found in much smaller quantities in the Appalachian region of the eastern states, and sporadically elsewhere in the region lying between the Appalachian and Rocky Mountains. Among the latter instances may be mentioned the Ropes mine in Michigan, where a gold-bearing vein was worked for a number of years, and many other places where a little gold has been obtained, but not enough to cut any important figure in the general production of the country.

At the present time the chief gold-producing regions in the United States are California, Nevada, Colorado, Alaska, South Dakota, Utah, Montana, Arizona and Idaho, while the first four produce by far the larger part of the American output.

Events Influencing Gold Discoveries in the United States

Several important events in the history of the United States have done much to stimulate the search for gold. In California the declaration of freedom from Mexico about a year and a half before the discov-

ery of gold, brought many adventurous people there who did much to develop the gold resources when found; in fact, the very discovery of gold was made in the building of a mill to supply the wants of the increasing population of California.

After our Civil War had ended, in 1865, many men who had served in both armies had become too much accustomed to constant excitement and action to settle down to the ordinary monotonous callings of life, and thousands of them started for the west as a country offering the life of adventure that they sought. Such men were thrifty, intelligent, brave and used to hardships. No pioneers of a new country were ever more suited to their task than they, and the result was soon seen in many new mining discoveries, made in the years immediately following the war.

Again, after the price of silver began to fall, many men were thrown out of work by the closing of the mines, and the search for gold attracted them as offering a more stable pursuit; with the result that in the years from 1890 to 1905 some of the great gold discoveries of the world were made, including the Cripple Creek, Klondike, Goldfield and other regions.

Financial panics and times of business depression have also marked epochs in the development of mining, especially gold mining. When manufacturing and other commercial pursuits are not prosperous, when men are thrown out of work, speculators financially ruined, banks closed and the whole world seems gloomy, then gold mining has often been most prosperous; for the unemployed and the unfortunate have taken to it as a means of earning a livelihood or of recuperating their shattered fortunes, and in doing so have often made rich discoveries. Many of the pioneers who came to Colorado in the 1859 rush were men who had suffered in the financial panic of 1857; and many of the early prospectors in the Cripple Creek region were people who had been similarly injured in the panic of 1893, while many a Klondike explorer had been a prosperous business man before the latter sad era. In the same way a marked increase in the production of gold in 1908 followed the financial panic of 1907. This feature of gold mining as a last help to the unfortunate has been observed not only in the United States, but in many other parts of the world. When all else fails, the people take to gold mining, especially placer mining, which requires but little equipment, is easily learned, and in some places is sure to afford a certain, though often meager, profit.

An important factor in the progress of gold mining has been the increased respect for the industry on the part of the public at large. Not many years ago, many people, especially in the east, looked on gold mining as a gamble and a calling of questionable character; and the numerous fraudulent schemes that had been floated gave them some

justification for their ideas. Many a person who sought to increase his fortune by mining, kept the matter a secret, so as not to injure his standing with his more conservative business associates. Since then, however, people have realized that there is good as well as bad in gold mining, as in every other business, and the credit of the industry has improved greatly, so that more and more interest is being taken in it.

Production of Gold in the United States[6]

The production of gold in the United States up to 1834 has been estimated at $14,000,000,[7] all of it from the southern states. In 1834 the annual production was about $1,000,000, and in 1853 the discoveries in California had increased it to about $65,000,000. Later, the exhaustion of some of the California mines caused the production of the United States to fall off, until, with various fluctuations, it sank to $31,801,000 in 1885. Since then the renewed interest in gold mining has increased the production. In 1895 it had risen to $46,610,000, and in 1905 it was $88,180,700, while in 1909 it reached $99,673,400, an annual production not known to have been exceeded to that time by any country except the Transvaal.

The total production of the United States in gold, since that metal was first mined in this country, in the early part of the last century, up to the end of 1909, has been $3,165,304,400.[8] When it is remembered that most of this immense sum has been produced since 1848, some idea can be had of its vast effect on the political and economic conditions, not only of the United States but of the world.

Future of Gold Mining in the United States

It is difficult to make accurate predictions about the future of any mining industry except from the mines already known, and even then such predictions are liable to grave error. The difficulty, however, becomes still greater when we discuss the possibility of the discovery of new mines, and this is especially true in the United States, where there are wide regions in which new mines might be found, but where no one can yet say that they do exist.

A striking feature of past experience is the fact that many of the greatest gold discoveries in the United States were made in regions that were already well known, and in some cases had been passed over

[6] Space does not permit giving here detailed figures of the production of gold in different parts of the United States, and only enough statistics are given to make the present paper intelligible. Fuller statistics are easily obtained in the Reports of the Director of the Mint, the "Mineral Resources of the United States" and the "Mineral Industry."

[7] Annual Report, Director of the Mint, 1910.

[8] Annual Report, Director of the Mint, 1910.

time and again by prospectors. The gold of the southern states was found in parts of the country that were well settled by an agricultural population, and yet for a long time it excited no attention. In this case the fact that the people had had no experience in gold mining was doubtless sufficient reason for this neglect; but when we see similar cases in the west, where mining has been the chief occupation of the people since the country was settled, the fact becomes more noteworthy.

The gold of California was discovered purely by accident, in a country which, though not exactly well known, had yet been passed over by many people, and was at least well enough known to warrant the existence of a mill, in the construction of which the gold was found. The Cripple Creek district was discovered in one of the best known parts of Colorado, in a region that had for many years been settled by ranchers. Year by year the cowboys and others, among them many miners, had passed over it without noticing the ore, and yet the latter was lying in lumps on the ground or protruding in outcrops in a way that made it a prominent feature of the neighborhood. Goldfield in Nevada was also discovered in a region that was well known to prospectors, and the ore occurred in large prominent outcrops, yet it lay for years ignored. The gold gravels of the Klondike had been trodden over by Hudson Bay trappers and the early miners of the Yukon for years before they were discovered.

Many other similar cases might be mentioned of new discoveries in well-known regions, where the gold was at last found by some inquisitive prospector having an assay made of a piece of strange-looking rock, which every one else had always seen but never thought of value, or by sinking a well for water, digging a ditch, planting a tree, or in walking over a place where the forest had recently been burned. The long delay in many of these belated discoveries was due to the ignorance of the prospector who could recognize certain ores but not others, while the general neglect of gold mining and the craze for silver mining in parts of the west for thirty years, from 1860 to 1890, was doubtless a contributing cause.

The fact remains, however, that the three greatest gold regions discovered in recent years, that is, the Cripple Creek, Klondike and Goldfield districts, were all found in well-known localities; and the question naturally arises, may not many other discoveries be made not only in the less explored parts of the west, but even in the shadow of the towns and ranches? One can not refrain from the conclusion that this is not only possible, but probable. Moreover, the better knowledge of the nature and occurrence of ores, which the prospector of to-day is gradually acquiring, will greatly assist in the search.

Aside from the possibility of new discoveries of gold, the improved metallurgical methods, the cheaper fuel, transportation facilities and

other conditions are constantly enabling the gold miner to treat ores of lower and lower grade. Ores that were once considered of too low grade to be of value are now treated at a large profit, and many a mine abandoned years ago as worked out has been reopened and has become very profitable; while the old waste dumps have been sorted over for ore that was thrown away as worthless in the early days.

In placer mining the same progress has taken place. The early work by hand with pans and cradles was replaced by sluices, then these by hydraulic machinery and sluices, while later the system of dredging the gravel was introduced. Each method marked a step in the economical evolution of gravel mining, and to-day in many parts of the west gravels are being worked which have already been handled several times over by older methods.

An important amount of gold comes as a by-product from the treatment of copper and lead ores, and to some extent zinc, iron and other ores, and as the amount of base metals mined is constantly increasing, the gold from this source will also probably increase.

When we consider the probability of new gold discoveries in the United States, the longer life of known mines under improved conditions, the increased production as a by-product from the base metals, the future of gold in the United States seems bright. For a long time to come the present production of approximately $100,000,000 yearly should easily be maintained and there is a strong probability that it may in time be greatly exceeded.

MODERN TENEMENT HOUSES

BY JONATHAN A. RAWSON, JR.
NEW YORK CITY

THERE are now being completed in New York City two groups of tenement buildings, which without doubt embody more real improvements in tenement house construction than have ever before been seen in any one structure. Both groups are on East 77th Street near the East River. One is being erected by Mrs. William K. Vanderbilt, Sr., and the other by the Open Stair Tenement Co. Henry Atterbury Smith is the architect in each case and similar buildings after his designs are soon to be erected in Hoboken and further downtown in New York, in West 47th Street.

Whether science, learning or practical common sense has contributed more to the latest improvements in tenement-house construction as revealed in these buildings, it would be hard to say, but whichever it is Mr. Smith deserves the credit. He has given many years to the study of this problem and it was some time after he worked out its solution before he was able to persuade capital to adopt his plans. All of

FIG. 1. EAST 77TH STREET, NEW YORK, LOOKING WEST. Vanderbilt Tenements on the right, and those of the Open Stair Tenement Company on the left.

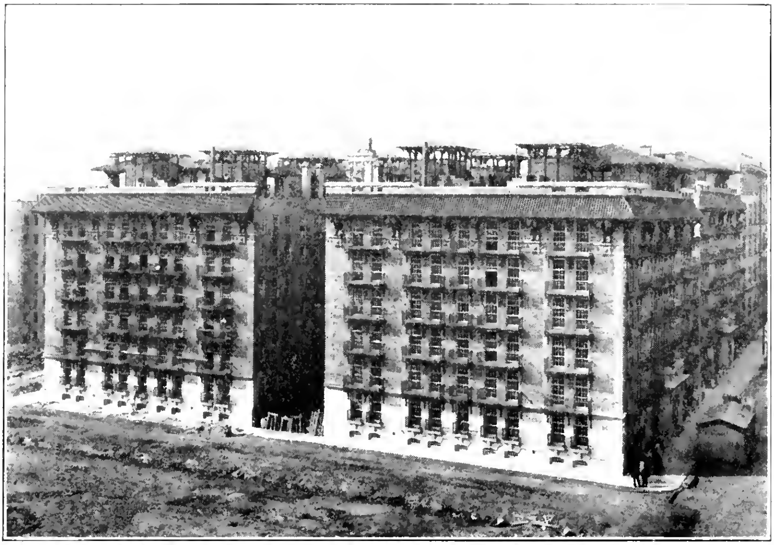


FIG. 2. THE VANDERBILT TENEMENTS.

that is now of the past, however, and the first of his buildings is now nearly ready for occupancy.

Mr. Smith's chief aim and purpose in the construction and arrangement of his buildings is to secure for them the greatest possible supply of fresh air and sunshine, and conversely to eliminate every opportunity for darkness and bad ventilation. Instead of erecting one immense structure broken only by the narrow shafts and congested yards of most tenement houses, he makes each building a group of four units, each surrounding a spacious central court. This court is entered through a direct, unobstructed passage from the street. One of these entrances is seen at the right of Fig. 1. From the central court there are recessed stairways in each corner extending all the way to the roof, and with private entrances directly into each apartment.

These are the open stairs which form the distinguishing characteristic of all the tenement houses designed by Mr. Smith. The primary purpose of these open stairs is to do away with all interior passages and hallways and to provide each family with its own entrance from outside the building. The open stairs are in reality open on one side only as shown in Fig. 3, which gives not only a view of the interior of one stair well, but also a view of the well in the opposite corner of the court as seen from outside. Every particle of material in the stairway is fireproof and hardly a crack or a crevice is left in which dust or dirt may collect. The railings are of iron, and midway between the floors are iron seats to serve as resting places. To keep out rain and snow there are hoods over these seats, projecting outward at the proper angle to

accomplish their main purpose without excluding air or light. Smooth glazed white tile on the walls of the well and large panes of thick glass in the hoods are designed to catch and reflect every available ray of light. There is nothing dark or dingy about such a stairway and its advantages over the foul-smelling, unsanitary halls of the average tenement are too apparent to require enumeration.

The top of each stair well is covered with a pergola like that shown in Fig. 4. The pergolas have iron framework holding glass panels over the top and glass windows part way up the sides, with numerous sections which can be opened when desired. Immediately under its roof the pergola is always open for ventilating purposes, but so that neither snow nor rain can find its way into the hall.

Another feature of the open stairs hardly less interesting than those already mentioned is their intensely practical usefulness in case of fire. It is a remarkable testimonial to their value in this respect that the city officials who pass on such matters have decided that no fire-escapes are required on tenements of the open stair type. The most practical fire proof quality of the open stairs is that they are the one means of leav-

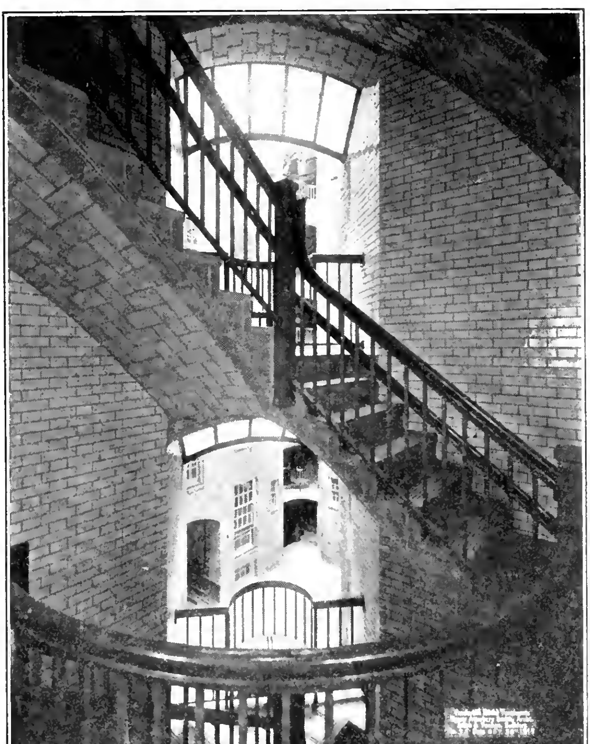


Fig. 3. The Open Stairs, with outlook beyond, across the central court and into the stair well of the opposite corner.

ing the building with which the tenants are always familiar—the exits towards which they would naturally hasten in case of danger, and further that they allow of escape either in two directions—to the ground in the central court or upward to the roof whence the tenant may cross to another well and then descend. Beginning with the fact that the building itself furnishes almost nothing for flames to feed upon, and then noting that two routes to safety are always available and that no tenant is ever shut off from a direct avenue of escape unless the fire is actually at his own threshold, where there is not enough for it to burn to assume dangerous proportions, and the case for the open stairs as effective

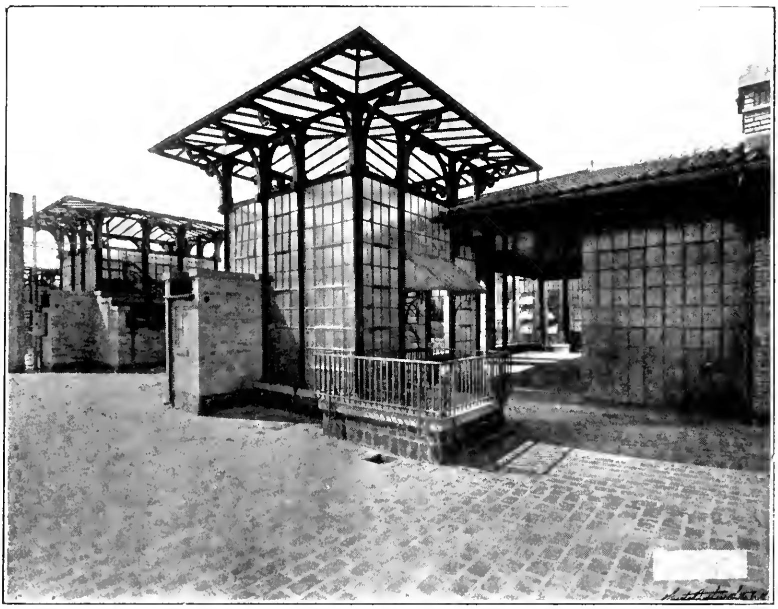


Fig. 4. On Roof of the Vanderbilt Tenements. The pergola in the center covers one of the open stair wells, and at its right is a covered shelter for the use of tenants.

preventives of fire or escape therefrom is rather strongly established. No fire could gain much headway in any part of a building of this sort without soon being detected and located, and prevented from spreading by playing hose from the central court upon the entrance of the burning apartment.

What the architect might designate as the fenestration of the periphery, but would be more easily recognized by the layman as the window treatment of the exterior, is another vital feature of the plan to secure the utmost circulation of air. In the Vanderbilt group as seen in Fig. 2 all exterior windows are extremely high, extending from floor to ceiling, and have sashes in three sections so that two thirds of the

FIG. 5. A KITCHEN IN THE VANDERBILT TENEMENTS, showing cement flooring with unbroken, curved joining of floor and walls; also the triple-hung windows.

window may be thrown open. Moreover, each apartment has a strong, spacious iron balcony reached through the windows. These balconies have no communication with each other and are sufficiently wide to be used as sleeping porches if desired. The arrangement of the rooms is such that no outside widows open on toilets or hallways. All of them are either in kitchens or bedrooms and in a great majority of the apartments there is a direct cross draught through the rooms, from the street side to the inner court, or from the courts separating the various units.

Both the roofs and the cellars of the Vanderbilt buildings are in a

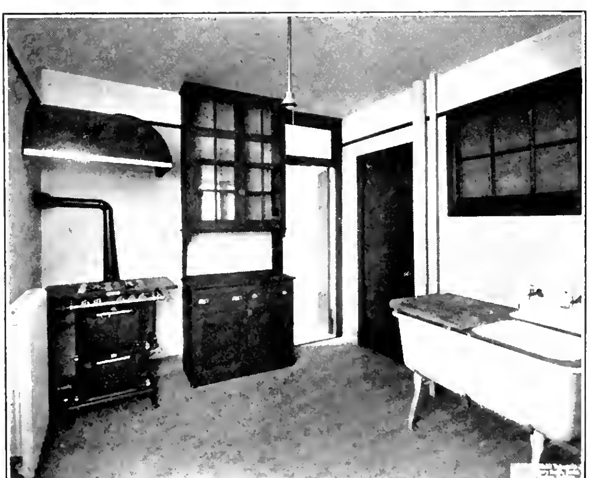


FIG. 6. ANOTHER VIEW OF A KITCHEN, showing hood over the gas range.

sense the common property of all tenants. In the basements are laundries for the use of tenants who prefer not to do their washing in their own rooms, and the roofs provide ample space where children may play or for older folks to rest or do their light housework in the open air.

Within the tenements, all the woodwork and structural furnishings are planned in the simplest possible way. There is no attempt at ornamentation, but everything is done to further the effort to secure cleanliness and wholesomeness. The floors are of concrete monolythic construction, or all of one solid surface and they have the sanitary base which means that they round up gradually into the walls with no sharp joints or corners.

The buildings are lighted throughout with electricity, but there are gas ranges for cooking over which are wide metal hoods which carry the odors and vapors from the stove into a flue which runs up into a pipe extending high above the floor of the roof. Sanitary earthenware is used in the bath rooms and for the set-tubs in the kitchens.

THE HISTORY OF GYMNOSPERMS

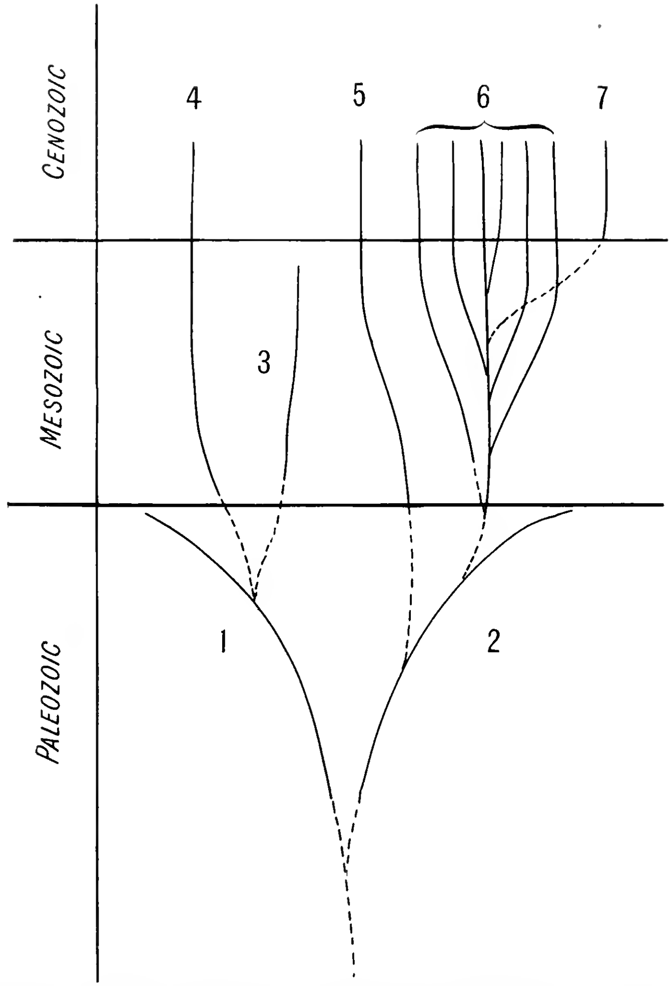
By Professor JOHN M. COULTER
UNIVERSITY OF CHICAGO

NO great group of plants seems to have left so continuous and full a record of itself, through so long a stretch of time, as have the Gymnosperms. Further work may uncover equally extensive records of certain other vascular groups, but our knowledge of the history of Gymnosperms is at present more complete than that of any other group of plants.

Several things have contributed to the completeness of this knowledge of Gymnosperms. They have always been abundant in the flora of every period that has left a plant record, and they are still abundant. This has given continuity and wealth of material throughout the whole history of vegetation, so far as that history is known. Those who picture an historical succession of the great plant groups are not representing the records in sight, for our earliest records show a vegetation as varied and complex as that of to-day, so far as the great groups are concerned. Although Angiosperms are probably relatively modern, seed-plants were represented early in the Paleozoic by Gymnosperms. This means that the evolution of the plant kingdom, in all its essential outlines, had been attained at least as early as any known records of vegetation.

Another fact which has contributed to the completeness of our knowledge of the group is what may be called the renascence of paleobotany as a morphological subject. Not only did this involve the comparative study, from sections, of the essential structures, but also it enormously extended the range of structures used in indicating relationships, by including the vascular system in the evolutionary scheme. The incorporation of vascular anatomy into modern morphology was significant not merely because it supplied another line of attack, but also because it deals with the most completely recorded structure of vascular plants and really gives continuity to the paleobotanical record.

The Gymnosperms were represented during the Paleozoic by two great groups, Cycadofilicales and Cordaitales. They were not merely members of the Paleozoic flora, but they were conspicuous members, together constituting the seed-plant vegetation. Neither of these groups has been traced with certainty into the Mesozoic, so that even though a few lingering forms may be found at a later period, they are essentially restricted to the Paleozoic, and our knowledge of them has been derived



Historical Connections of the Groups of Gymnosperms: 1, Cycadofilicales; 2, Cordaitales; 3, Bennettitales; 4, Cycadales; 5, Ginkgoales; 6, Coniferales; 7, Gnetales.

chiefly from material obtained from the Coal-measures. Although the two groups are equally ancient, so far as our records go, having been recognized well into the Middle Devonian, it is quite evident from comparative structures that the Cycadofilicales are the more primitive, and presumably the more ancient. Whether they are actually the most ancient seed plants or not, they are at least the most primitive seed plants of which we have any knowledge.

The presence of this great group of primitive seed plants (Cycadofilicales) in the Paleozoic was obscured for many years by the impression that they were ferns. A very large percentage of the Coal-measure

vegetation consisted of these fern-like plants, and so the coal period was pictured as a time of luxuriant fern vegetation, rivalling our present tropics in that feature. Approximately ten years ago these fern-like plants were observed to bear seeds, and the Cycadofilicales became established as the most fern-like group of Gymnosperms. All of the great Paleozoic "fern" groups were found involved in the seed-bearing habit, until now the residuum of real ferns in the Paleozoic seems to be quite small. In any event, it has been made clear that the Cycadofilicales were derived from ferns; and if so, probably all the other Gymnosperms. It should be understood that the ordinary ferns of to-day are relatively modern, and are quite unlike those very ancient ferns which gave rise to the Cycadofilicales, and which have received the general name Primofilices.

This ancient group of Gymnosperms resembled ferns in every important particular except in the seed-bearing habit. Whereas in ordinary ferns the sporangia are borne in groups or so-called "fruit dots" (sori) on the fronds, in Cycadofilicales some of the sori were replaced by seeds, which makes a seed the morphological equivalent of a sporangium or a group of sporangia (a sorus). The bearing of seeds necessitated also the presence of structures corresponding to stamens, and producing pollen. These pollen-bearing structures remained like the fern sporangia (in sori), and for a long time confirmed the notion that these fern-like plants were really ferns. To say that a fern-like leaf must belong to a fern might be unsafe, but to say that such a leaf bearing sporangia in sori must belong to a fern seemed absolutely safe. And still many of these "fern sporangia" have turned out to be the pollen sacs of seed plants.

If the bearing of seeds distinguished Cycadofilicales from ferns, the absence of cones distinguished them from other Gymnosperms. The seeds and pollen sacs were borne as freely on the fronds as are the sporangia on the fronds of ferns. In the later groups of Gymnosperms, the seed-bearing leaves and pollen sac-bearing leaves (both kinds called "sporophylls") became distinct from the ordinary foliage leaves, and were finally compactly organized into the cone-like structure (strobilus) characteristic of most Gymnosperms. But among the Cycadofilicales the strobilus stage was not reached.

The Cycadofilicales seem to have given rise to two great branches of Gymnosperms, both of which are represented in the present flora. One of them includes the Cycads, and therefore have been called the Cycadophytes; the other includes the Conifers, and therefore may be called the Coniferophytes. The Coniferophytes differentiated from the Cycadofilicales earlier than our records of vascular vegetation, for the Paleozoic representative (Cordaitales) of Coniferophytes is distinct from the Cycadofilicales as far back as records go. On the other hand,

the Cycadophyte branch is not distinguishable until the Mesozoic.

Historically, therefore, the Cordaitales must be considered as the second group of Gymnosperms. Their connection with an ancient fern stock is evident in their structure, but they have lost many of the fern characters that were retained by Cycadofilicales. The fact that Cordaitales are much further from ferns than are the Cycadofilicales is perhaps the best proof that they have come from the ferns by way of the Cycadofilicales. The combination of changes involved in their structure is all in the direction of the later Conifers, as, for example, the branching stem (constituting what is called "the habit") with its thick cylinder of secondary wood, the narrow and entire leaves, and the cones (strobili). It would not fit the purpose of this presentation to include the changes in the more intimate structures, since their nature and significance can be appreciated only by the special students of the group, but they are just as striking as the more obvious changes mentioned.

The Gymnosperm vegetation of the Paleozoic, therefore, comprised two great genetic groups: the Cycadofilicales, representing the primitive Gymnosperm stock that differentiated from the ferns; and the Cordaitales, representing the primitive Coniferophyte stock that differentiated from Cycadofilicales more ancient than those we know.

In the Mesozoic flora the Gymnosperms were represented by four great groups, evidently derived from the two Paleozoic groups. As stated above, the Cycadophyte branch became distinct, and for a long time all of its representatives were thought to be Cycads. For this reason, the Mesozoic has been called the "age of Cycads," so far as the vegetation is concerned. It is one of the triumphs of American paleobotany that it has put on a firm basis our knowledge of the great Cycadophyte group of the Mesozoic, and has shown that it is quite different from the modern Cycads. The group is called Bennettitales, and although a few forms from foreign localities have been known for a long time, it remained for Mesozoic deposits of the United States and Mexico to reveal a remarkably rich display of forms in admirable preservation. The investigation of this material has been carried on chiefly by Dr. G. R. Wieland of the Yale Museum.

The Bennettitales, therefore, are the so-called "fossil Cycads" of the Mesozoic. So far as the records show, they are restricted to the Mesozoic, so that they represent an extinct Mesozoic group, just as there are two extinct Paleozoic groups. Of course it is not only conceivable, but also probable that the Paleozoic Cycadofilicales, from which Bennettitales were derived, continued into early Mesozoic; and that the Mesozoic Bennettitales began to differentiate in late Paleozoic. The external appearance of Bennettitales justifies their early assignment to the Cycads, for the whole habit is Cycadean. The stems are either tuberous or cylindrical, and crowned by a rosette of large, fern-like

leaves, giving to the cylindrical forms the appearance of tree ferns. The remarkable feature of Bennettitales, however, is the cone (strobilus), whose structure is unique among Gymnosperms. These cones, instead of being solitary and terminal, in the midst of the rosette of leaves, as in most Cycads, are lateral on dwarf branches which arise in profusion from the stem. But this is a small feature as compared with the fact that the cone is "bisporangiate." In other Gymnosperms the ovules (and of course seeds) and stamens are in different cones, and often these cones are on different plants. In Bennettitales, the rosette of stamens, which resemble small fern fronds bearing sporangia, subtends the more or less extended axis-bearing ovules, and both stamens and ovules are encased by enveloping bracts. This bisporangiate character, and the relation of stamens to ovules in the cone, are so suggestive of such an Angiosperm flower as that of magnolia that some botanists would see in Bennettitales the ancestral forms of Angiosperms. It is certainly true that the Bennettitales were abundant and wide-spread during the Mesozoic, and it seems to be true that the Angiosperms originated during the Mesozoic.

The Cycads (Cycadales) constitute a second group of Mesozoic Gymnosperms, associated with the Bennettitales of common origin, but apparently not a conspicuous part of the vegetation. It is very likely true that Bennettitales and Cycadales represent two independent Mesozoic derivatives from the Paleozoic Cycadofilicales: that the Bennettitales attained a dominant place in the Mesozoic flora; and that the Cycadales, much less conspicuous during the Mesozoic, persisted until the present day as the only living representatives of the Cycadophytes.

The Cycadophyte line is characterized by the retention of many of the fern-like features of the Cycadofilicales. In habit, in foliage, in stem structure, in sporangia, in reproductive habits, the features of Cycadofilicales were continued; so that the living Cycads, although relatively modern from the standpoint of history, are structurally the most primitive of living Gymnosperms, because they most resemble the historically ancient Cycadofilicales.

The two other groups of Mesozoic Gymnosperms were derived from the Paleozoic Cordaitales, the Paleozoic member of the Coniferophyte branch. They are known as Ginkgoales and Coniferales, the former being nearly or quite extinct to-day, and the latter comprising the present conspicuous Gymnosperm vegetation of the temperate regions.

The Ginkgoales were abundant during the Mesozoic, but apparently remained quite constant in characters, so that they can be represented structurally by a single line extending from the late Paleozoic to the present time. They are really a Mesozoic type, and their single representative in the present flora has probably continued to exist simply because it is a tree kept in cultivation in the temple grounds of China

and Japan. Of course Ginkgoales continued all the features of Cordaitales that looked towards Conifers, such as the branching habit, relatively simple leaves, and thick vascular cylinder. The monosporangiate cones were also continued, but the most notable feature is the continuation of the swimming sperms of Cordaitales. Cordaitales had continued the swimming sperms of Cycadofilicales and ferns; in fact all the vascular plants of the Paleozoic had swimming sperms. One of the most primitive features of the Cycadophyte branch is that it retained throughout this primitive, fern type of male cell. In the present Gymnosperm flora, therefore, Cycads and Ginkgos are distinguished by having swimming sperms, the former having continued them directly from the Cycadofilicales, the latter obtaining them indirectly from the same source, and directly through the Cordaitales. To state the situation in other terms, it may be said that the Cycads have continued primitive vegetative and reproductive structures, while the Ginkgos have retained primitive reproductive structures and have changed the vegetative structures, a change initiated by the Cordaitales.

All of this serves to emphasize the position of the Coniferales, the fourth Mesozoic group, and the dominant Gymnosperm group to-day. It not only continued to change the vegetative structures, but it also abandoned the primitive features of reproduction in abandoning the swimming sperm, which became a relatively passive cell conducted to the egg by a pollen tube. Few persons realize that Gymnosperms in general, in terms of great groups, have swimming sperms, which the pollen tubes do not conduct; for this situation is overshadowed by the fact that the single overwhelming group of Gymnosperms to-day has passive sperms conducted by pollen tubes.

In connection with this change of reproductive habit, the Coniferales during the Mesozoic differentiated into the six great families or tribes recognized to-day, so that it is the one great group of Gymnosperms that developed an extensive range of forms. The historical interest connected with Conifers, therefore, is not so much the origin of the group as a whole, for that seems to be traced clearly to the Paleozoic Cordaitales, as the origin and relative antiquity of its tribes. This question has been answered by the study of vascular anatomy, chiefly by Jeffrey of Harvard, supported by the morphology of the reproductive structures, and by history. The conclusion is that the tribe containing the pines is to be regarded as including the modern representatives of the most ancient Conifers. The only possible contestant for this honor is the tribe comprising the araucarians of the southern hemisphere. The four other tribes (podocarps, taxads, taxodiums and cypresses) are clearly relatively modern. The general conclusion, therefore, is that the Conifer stock became differentiated from the Cordaitales with features characteristic of the pine tribe, and that from this

primitive stock the other tribes separated later, and the pine tribe itself became more modern.

The history of Gymnosperms is not complete without mention of its seventh great group, the Gnetales. They comprise three genera, extremely unlike in habit, habitat and geographical distribution, but held together by certain important characters. They are so different from other Gymnosperms that no phylogenetic connection is clear, and there is no sure record of them as fossils. This seems to indicate that they are very modern, but their dissimilarity and their wide separation from one another geographically make it certain that if they are genetically related they must have a history that remains to be discovered. Such suggestions of connection as can be obtained indicate as a possibility that Gnetales are derivatives from the prolific Coniferales stock.

Dr. Edward C. Pickering,
Director of the Harvard College Observatory, President-elect of the American Association for the Advancement of Science.

THE PROGRESS OF SCIENCE

THE WASHINGTON MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE American Association for the Advancement of Science and the societies affiliated with it held an unusually successful meeting in Washington during Christmas week. This, the sixty-third meeting of the association, was the largest in its history, the registration of its members being 1,306. There is no practical advantage in registering and at Washington the places of meeting were so widely scattered that many members failed to register. The secretary of the council estimates the total attendance of members of the association and of affiliated societies at 2,800.

The association had the privilege of being welcomed to the capital of the nation by its president, who in his address exhibited an appreciative interest in the scientific work done under the government and in the investigations of scientific men. He said that if he had the power he would place an astronomer at the head of the U. S. Naval Observatory. President Taft must have paid what he regarded as a high compliment to the work of a scientific man when he compared it with that of a judge. Indeed he placed the work of the bench even higher than might have been expected, for he said that it is the duty of a judge to find a final solution in accordance with "eternal justice," whereas it is commonly supposed that a judge must interpret temporary laws. Dr. Charles E. Bessey, head of the department of botany at the University of Nebraska, president of the association, in reply to the address of welcome, called attention to the fact that scientific men are like those who occupy legislative, judicial and executive positions, in that they work for the good of the community rather than for their own advancement; but whereas the politician works only in the present and for the present, the scientific man, like the statesman, must look before and after. Dr. Bessey also called attention to the need of giving scientific men in the Washington bureaus the opportunities most favorable to scientific research. The annual address was then delivered by President A. A. Michelson, head of the department of physics in the University of Chicago, whose subject was "Recent Progress in Spectroscopic Methods." Dr. Michelson traced with such clearness as to hold the complete attention of the audience the important researches in which he himself has taken such a leading part.

It is quite out of the question to describe the work of the eleven sections of the association and of the thirty special societies which met at Washington. The titles of the papers presented would fill a considerable part of an issue of the MONTHLY, and the papers themselves would fill its volumes for years to come. The addresses of the president and of the vice-presidents have been printed in SCIENCE, where also will be found accounts of the proceedings of the association and of the various societies and some of the addresses and discussions presented before them. Here we can only call attention to the wide scope and great quantity of research work being carried forward in this country and adequately represented at the Washington meeting. The only drawback to our satisfaction is that there appear to be no advances or discoveries of such outstanding importance as to deserve special recognition.

Dr. Edwin B. Frost,
Director of the Yerkes Observatory,
Vice-president for Mathematics
and Astronomy.

NEW UNIVERSITY PRESIDENTS

There is no decline in the birth rate of university presidents. Within a few months President Vincent has been installed at the University of Minnesota, President Brown at New York University, President Murlin at Boston University, President Hodges at the University of West Virginia, President Benton at the University of Vermont and President Bowman at the State University of Iowa. The deadlock at Princeton University has been broken by the election of Dr. John Grier Hibben, Stuart professor of logic, after the offer of the position had been declined by Dr. J. M. T. Finney, the Baltimore surgeon. It seems that any one who has attended one of these functions of installation, where many presidents gather on the stage, must have noticed the diversity of type, the scholar and the politician, the man of science and the promoter, the hereditary gentleman and the climber, all being in evidence. A gift for oratory seems to be almost the only common trait and even here the variety is more noticeable than the similarity.

One may wonder what trait or ac-

Dr. Robert A. Millikan,
Associate Professor of Physics at the
University of Chicago, Vice-
president for Physics.

Dr. Chas. S. Howe,
President of the Case School of Applied
Science, Vice-president for Mechanical
Science and Engineering.

cident has given these gentlemen the extraordinary position they hold in higher education and in the community. In *The Educational Review*, for November, President Eliot, whose ability, persistence, personality and long tenure of office have been important factors in developing the autocracy of the presidential office in the university and its function as general adviser on all subjects in the community, writes pleasantly about "The University President in the American Commonwealth." He says: "Most American professors of good quality would regard the imposition of duties concerning the selection of professors and other teachers, the election of the president, and the annual arrangement of the budget of the institution as a serious reduction in the attractiveness of the scholar's life and the professorial career." The question arises how one who knows so little about the thoughts of professors can adequately fulfill the paternal function, and whether the kind of persons the president thinks the pro-

Dr. George T. Ladd,
Emeritus Professor of Philosophy at Yale University, Vice-president for Anthropology and Psychology.

Dr. Edward L. Thorndike,
Professor of Genetic Psychology at Teachers College, Columbia University, Vice-president for Education.

Dr. J. Pease Norton,
Yale University, Vice-president for Social and Economic Science.

fessors ought to be will provide presidents for the future. And if there were no university presidents, what would become of the nation?

SCIENTIFIC ITEMS

We record with regret the deaths of Major Clarence Edward Dutton, U.S.A., retired, eminent for his contributions on volcanoes and earthquakes; of Miss Susan Maria Hallowell, professor emeritus of botany in Wellesley College; of Mr. George R. M. Murray, F.R.S., for many years on the staff of the department of botany of the British Museum, and of M. Paul Topinard, the distinguished French anthropologist.

President Taft has nominated Dr. Rupert Blue, of South Carolina, as surgeon general of the public health and marine hospital service.—M. Henri Bergson, professor of philosophy at the Collège de France, has been appointed visiting French professor of Columbia University for the year 1913. M. Bergson has also been appointed Gifford lecturer at Edinburgh.—The Academy of Natural Sciences of Philadelphia has awarded the Hayden Medal in gold for distinguished work in geology to Professor John C. Branner, of Leland Stanford Jr. University.

The organ of the Japan Peace Society gives an account of the visit of Dr. David Starr Jordan, president of Stanford University, in August, September and October, undertaken under the auspices of the Japan and American Peace Societies. Dr. Jordan gave a large number of addresses, mainly on peace and arbitration, at Tokyo, Yokohama, Sendai, Nagoya, Okayama and Osaka. At Tokyo between September 13 and 18 he gave as many as ten formal addresses.

THE

POPULAR SCIENCE

MONTHLY.

MARCH, 1912

GLIMPSES OF THE GREAT AMERICAN DESERT

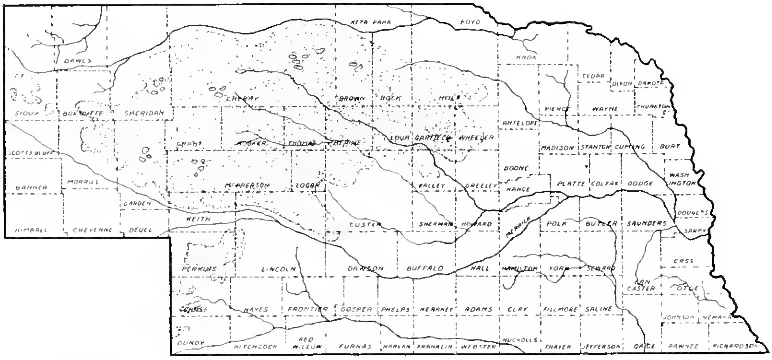
By Professor RAYMOND J. POOL

THE UNIVERSITY OF NEBRASKA

THOUSANDS of years ago when the forces of nature were at work shifting and gradually shaping the features of the Great Plains, large areas of Tertiary sandstones were exposed in Dakota, Wyoming, Nebraska, Kansas and other parts of the western plains. As topographic features were slowly evolved, these sandstones, being young and soft, readily yielded to the eroding action of the elements and were reduced to light, fine-grained sand. In addition to this sand formed *in situ* probably considerable amounts of other sands were washed or blown into the region from farther west. Great quantities of the sand thus formed were caught up by the wind and heaped into mounds that finally grew to be large sand dunes extending in long ranges and ridges for many miles over the sandstone beds. Thus were the Sand Hills of the Great American Desert formed in the days preceding the advent of plants or men into the regions now characterized by the billowy hills covered with the bunch-grasses and their associates.

The Sand Hill landscape in these early days was probably a restless maze of wandering sand dunes. In later years certain plants crept in from the surrounding plains, only to be uprooted and blown away. After many such invasions some individuals finally succeeded in maintaining a foothold in the more protected portions of the hills. Notwithstanding the terrible conditions imposed by an arid climate and a continually shifting soil, vegetation continued to spread to other areas from these primary centers of establishment.

Some time after the Sand Hill flora had gained a lasting hold upon the dunes and the greenish hue of vegetation had spread over the great expanse of hills, enormous herds of bison came charging into the region



THE SAND HILL AREAS ARE INDICATED BY THE SHADED PORTIONS ON THE MAP.

in quest of forage. The vegetation was closely grazed and tramped into the unstable soil. And then the red man came, who killed the bison for food, clothing and for many other useful purposes. He sought to improve the range for the wild beast and for his own stock by burning the grass at certain seasons of the year. In this way a third and still greater menace was forced upon the plants that were struggling so hard to cover the Sand Hills with a permanent mantle of vegetation.

The Sand Hill region of Nebraska is one of the largest and best known portions of the sand hills of the Great Plains. In our state the main body of Sand Hills is oblong in shape with irregular margins. This region lies north and west of the central portion of the state. On the northern edge of the region there are numerous deep canyons with steep, more or less wooded sides. A few more or less isolated areas of Sand Hills occur outside this great main region both north and south of the Platte. A glance at the accompanying map will show the location and comparative size of the main region and the outlying areas of sand hills.

The Sand Hills of Nebraska cover an area of more than 18,000 square miles, almost one fourth of the total area of the state. This is about equal to the combined areas of New Hampshire and Vermont. The hills are all round-topped or conical and smooth, clearly showing that they had been shaped by the wind long before their invasion by plants. There are many depressions between the hills, many of which assume the proportions of valleys more than a mile in width and sometimes many miles in length. From these well-developed valleys the low places decrease in both width and length until they are mere narrow, saucer-shaped basins or "pockets" a few hundred yards across. The well-pronounced valleys are, as a rule, about parallel and trend in a general southeast and northwest direction. Such valleys are frequently completely inclosed by ranges of hills and in this way effectively separated from adjacent valleys, though such may not be more than a half

mile distant. Sometimes instead of the valleys being separated by a range of round-topped hills this is accomplished by a continuous rounded ridge. The sides of these hills are often very steep, making difficult the direct passage over from one valley to another.

In the regions of widest valleys the ranges of hills often show a succession of higher hills as one passes back from the valley to the highest points on the divide, which may be from 300 to 400 feet above the level of the valley. In the regions characterized by short valleys and basins the general landscape is strikingly different because in such places the hills rise on all sides without any regularity. Low hills, intermediate hills and high hills are all closely associated, with no long separating valleys. The result is a very abruptly rolling surface with rounded or oblong depressions of varying depth, with the rounded or conical dunes above. There are places where this sort of topography stretches in all directions as far as one can see.

As the name implies, the hills are composed of sand. This sand is of a light straw color (not white) composed mostly of fine grained quartz. The purest sand is found in the newest soil areas such as in "blow-outs" or other places where the overlying vegetation has been completely removed by the wind. In many places, notably on the river flats and in the numerous thickets scattered throughout the hills, there is a copious admixture of organic remains and so the surface soil in such places is a rich black sandy loam and is very fertile. But the characteristic soil of the region as a whole is the pure dune sand composed of very fine particles. As to the chemical nature of the sand, the following table shows it to be very high in insoluble mineral matter and very low in soluble organic or inorganic plant-food materials.

COMPOSITION OF SAND HILL SOIL[1]

	From Forest Nursery	From Tops of Hills
Insoluble matter	91.80	97.40
Potash	0.14	0.05
Soda	0.42	0.42
Lime	0.38	0.12
Iron oxide	0.01	0.01
Alumina	2.76	0.84
Phosphorus pentoxide	0.06	0.03
Sulphur trioxide	0.19	0.21
Water and organic matter	4.24	0.92
Total	100.00	100.00

The following table shows the size of the soil particles in per cent., and the average of three determinations from different stations in the Sand Hills:

[1] From a series of analyses by Dr. Samuel Avery, 1905.

Size of Soil Particles[2]

Size in mm.	2.0–1.0	1.0–0.5	0.50–0.25	0.25–0.10	0.10–0.05	0.05–0.01	0.01–0.005	0.005–0.0001
Station 1......	0.00	0.12	3.28	70.05	22.29	1.14	0.23	2.12
Station 2	0.00	0.41	8.59	46.62	39.56	0.86	0.28	3.35
Station 3	0.08	1.15	8.20	40.07	39.17	2.98	0.63	5.05
Average of 3 stations.....	0.02	0.56	6.69	52.24	33.67	1.66	0.38	3.50

Such a loose sandy soil soaks up moisture very readily, so that after a heavy fall of rain scarcely any water is drained from the surface into the valleys, but all of it goes into the porous soil. Now and then rainstorms of such torrential fierceness occur in the hills that a great quantity of the sand is brought down from high on the hills and carried into the valleys. Such storms are, however, exceptional, since the usual heavier rains of about 1.0–1.5 in. are completely taken up by the sand, with no surface drainage at all.

In connection with the distribution of soil water in the Sand Hills it is interesting to note that, although the surface of the sand is commonly as dry as powder, the sand but a few inches beneath the surface is quite moist. The average of many soil samples taken during July, 1911 (a wet month for that year), in widely isolated stations at a depth of twelve inches, showed the water content to be 3.27 per cent. The Sand Hills rest upon a series of relatively impermeable clays and stratified rocks. These layers of more solid materials crop out from the surface along streams and on the lower slopes of some hills quite remote from the deeper valleys. The soil is always moister upon a slope with these outcrops than in situations where such are absent.

The annual precipitation over the main body of Sand Hills varies from twenty-three inches in the east to about fifteen inches on the western border. April, May and June are usually the wettest months of the year, while the dry season frequently continues from August to March or the first of April.[3] In the central Sand Hills during the month of July, 1911, five and one half inches of rain fell. At the government forest nursery near Halsey (Thomas County) during this month there was scarcely a day that rain did not fall. The showers were usually light, but a few were soaking rains. Hail sometimes accompanies these thunderstorms in such quantity that a great amount of damage is done to gardens, crops and other property.

Most of the precipitation disappears into the soil at once. It is a rare sight, if indeed it ever happens, that any of the streams or lakes of the region show an increase in volume resulting from the run-off from

[2] From Professor E. H. Barbour, Nebr. Geol. Survey, Vol. 1, 1903.

[3] Data from official records of U. S. Forest Service at Halsey, Nebr., for last seven years.

even the heaviest downpour. Because of the general porous nature of the soil the region is characterized by sub-surface drainage. The fluctuations in the ground water from time to time produce differences in the level of the lakes and ponds. During especially wet seasons the level of the lakes may be perceptibly elevated, due in all probability to seepage from the surrounding hills.

The most important stream of the Sand Hills is the Loup River, the three forks of which rise in low swampy flats toward the central portion of the region. Through the Sand Hills portion of its course the Middle Loup has a fall of about eight feet per mile and so develops considerable current which causes its bed and its channel to shift continually. The sand banks are cut and the channel veers from side to side along its course. This tendency culminates in the formation of many "oxbows"

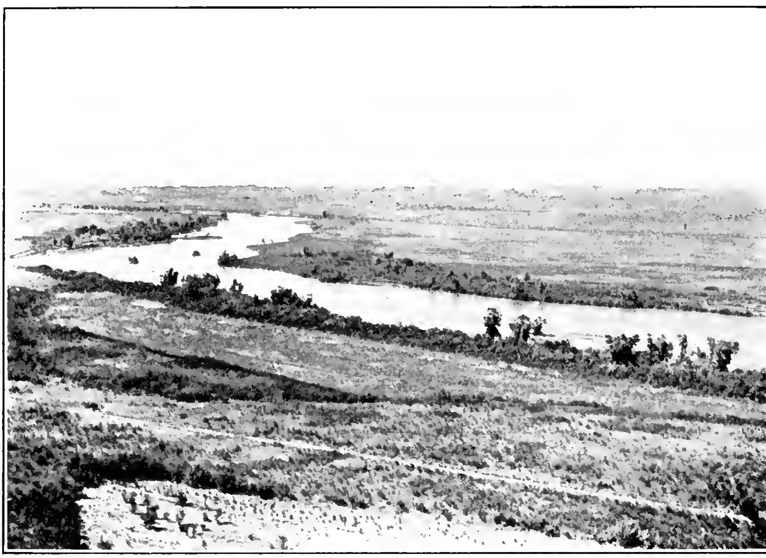


FIG. 1. THE MIDDLE LOUP RIVER WITH FRINGES OF WOODY VEGETATION. Sand Hills in the distance.

or loops. Some of these loops are most perfect and beautiful as viewed from far up in the hills. The streams of the region are all shallow, the Loup varying from one to six feet in depth with a channel about fifty yards wide. In many places such streams are extremely beautiful with their winding channels of clear swift water and fringes of vegetation.

The Dismal River is an important tributary to the Loup. Heading in the swamp and lake region of Hooker, Grant and McPherson counties, it continues eastward for about seventy-five or eighty miles, and pours into the Loup at Dunning. This river is an especially welcome sight as

one suddenly comes upon it hidden in a deep valley (almost a gorge in many places) after a long, slow, hot ride of thirty miles or more over the hills. The Dismal has cut in a number of places a very deep canyon through the hills. Often the sides of this canyon are almost perpendicular, while elsewhere the banks are not so high or steep. Now and then the stream leaps over a ledge of sandstone producing a waterfall a few feet in height which adds to the beauty of the landscape. There are in truth many spots along the Dismal that would make worthy subjects for the landscape painter.

Few would classify Nebraska among the states with lakes, but as a matter of fact there are hundreds of lakes in the state. Many of these lakes are in the Sand Hills, where they usually occur in groups of few to many in various parts of the region. The largest group occurs in Cherry County, with fifty or more lakes. Some of these, such as Hackberry, Dad's, Clear, Willow, Dewey, Red Deer, etc., furnish excellent sport to the fisherman and the hunter. Aquatic vegetation furnishes abundant food for both fish and fowl. The lakes vary from small ponds a hundred yards across to bodies of water a mile or more wide and four to five miles long. From the top of a certain hill in Cherry County more than twenty such lakes may be seen.[4]

There are many people who still think that the Sand Hill region is a plantless waste of wandering dunes. This is far from fact, but nevertheless the vegetation of the region is sparse and there are also many instances of actively moving sands, although by far the greatest portion of the area is effectively protected from wind erosion by the presence of vegetation. Nowhere except in the moister habitats, as in the valleys, do the plants grow densely or close together. On the hills proper the light-colored sand always shows between the individual plants. In places one may cross over areas two hundred yards or more in width and count all of the plants in his path on his fingers.

Notwithstanding the sparseness of the vegetation there are very many species represented in the Sand Hill flora, but in spite of this great number of species that are found over the hills and ridges and in the valleys, the most striking characteristic of Sand Hill vegetation is its great monotony due to the domination of bunch-grasses, which are the controlling elements of the floral covering of the whole region. The bunch-grasses are so named because from each root there arise many straight, wiry stems in close proximity, so that a clump or bundle of fifty to a hundred or more stems are densely crowded together. These bunches occur more or less scattered in a way such that the characteristic tufted nature of the vegetation results, and the numerous smaller species that occur in the intervals are quite effectively concealed.

[4] Pound and Clements: "Phytogeography of Nebraska," 1898.

A continuous association composed of bunch-grasses is the typical vegetation of the whole Sand Hill region. This covers the hills and ridges over thousands of square miles, being absent only from the "blow-outs" and the moister valleys. Once established in the sandy soil the bunch-grasses cope very successfully with the fury of the wind and the shifting sand. However, if fire or over-grazing seriously reduces the bunches in size and vitality, subsequent winds may uproot and carry them away. But on the whole the bunch-grasses are very effective sand binders, and it would be a great calamity indeed if they

Fig. 2. A frequent Sight: Over-grazing often Results in Bare Hills and Blowing Sand.

were to be removed and nothing substituted. It is due to them more than to any other single type of plants that the vegetation of the hills is enabled to persist. Within the shelter of the bunch-grass association scores of valuable species thrive that in its absence would never have found access to the region.

The bunch-grass *par excellence* is the little blue stem (*Andropogon scoparius*), but associated with it are others, such as sand grass (*Calamovilfa longifolia*), and needle grass (*Stipa comata*). *Andropogon scoparius* is the dominant species throughout the region, the other species being present only occasionally. It is the little blue stem that gives the first greenish hue to the sand hill landscape in the spring, and it is the same species that clothes the hills with the rich reddish-purple in the autumn and through the winter. Hall's blue stem (*Andropogon hallii*), common on the upper slopes of the hills and the tops of ridges, is usually of secondary importance. Its few tall whitish or bluish stems

in poorly defined bunches are, however, conspicuous wherever they are found.

Within the bunch-grass association there are a number of secondary types that are quite well defined. But as one views the vegetation of the Sand Hills in a general way these are lost in the great monotony of the bunch-grass association. However, the vegetation and general life conditions of the uplands, the home of the bunch-grasses, are very noticeably different from those characters on the river flats or in the wet valleys. The exposure to both the drying and the mechanical effects of the wind is most keenly felt on the uplands, composed of the hill tops and upper slopes. Sometimes the wind sweeps over the crests of the hills with such terrific force that one can not stand in its path and endure the sting of the sand blast. During a bright day with a high temperature and such a wind, life on the hills is well nigh impossible. During the hottest days of summer the surface sand in such situations is frequently heated to a temperature of 140° F. Such conditions with a low water content of the soil and a high saturation deficit are the factors that plants must meet. One can not but admire the vegetation that possesses the power of successfully resisting such a combination of conditions. That Sand Hill vegetation has been very successful in meeting these conditions is fully attested by a glance at the region as we find it to-day and a comparison with the dismal waste of bare sand dunes that once wandered over this same area.

Aside from the bunch-grasses, the most characteristic plant of the uplands is the dagger weed (*Yucca glauca*) which often occurs in great abundance on the upper slopes. In certain portions of the region over restricted areas this species really becomes dominant and the bunch-grasses then play only a subordinate part in the floral covering. The dagger weed reaches its best development on the south and west exposures, although it is by no means confined to these slopes. The sand is often blown away from the roots for many inches beneath the rosette of bristling leaves, and yet the plant continues to thrive. Frequently it puts out new shoots from the exposed roots and develops new rosettes of leaves beneath the old.

The so-called "cat steps" formed on steep slopes in the Sand Hills owe their origin to the grazing habits of cattle and very frequently to the presence of dagger weeds. On such slopes the cattle, avoiding the sharp-pointed leaves of the *Yucca*, follow angling paths which eventually become netted and worn into the sand in such a way as to cover the hillside with a network of trails. Clumps of dagger weed often fill in the more or less diamond shaped meshes of this network. From a distance, such a slope bears a close resemblance to the "cat steps" so commonly seen on steep slopes in the loess region. The origin is, however, very different. One may find in the Sand Hills a great many stages in

the development of these netted trails. They are not necessarily always associated with the dagger weed, since they also occur on slopes with bunch-grasses only.

Like the little blue stem, the dagger weed has little value in the region aside from its interesting and important rôle in the life history of the ridges and slopes. Some economic value is attached to it in that it is eaten by cattle to a slight degree. Especially when the plant is in bloom, if the range is rather short, stock frequently strip every juicy flower from the large spike or panicle, sometimes even eating the axis well down among the needle-tipped leaves. I have seen them attack the young capsules when the range is especially short, so that in a closely grazed pasture one seldom finds a single fruit of the species.

FIG. 3. THE DAGGER WEED IN FRUIT.

Besides the bunch-grasses and the dagger weed there are many other species that occur in greater or lesser frequency in the bunch-grass association. The hairlike eragrostis (*Eragrostis trichodes*) is an important secondary grass of the uplands that frequently shows the bunch-grass habit. So also Indian millet (*Oryzopsis cuspidata*), and the black grama grass (*Bouteloua hirsuta*) are quite commonly seen in the intervals between the bunch-grasses. In fact there are more than one hundred species of grasses alone in the Sand Hills, many of which are confined to the uplands. Besides the species already mentioned the following are other common associates of the bunch-grasses: Annual eriogonum (*Eriogonum annuum*) which, with its slender, gray flowering stems and conspicuous flat-topped clusters of flowers, occurs as widely

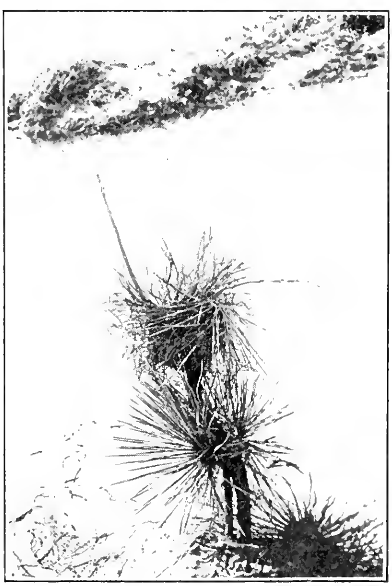


FIG. 4. THE DAGGER WEED MAY ADJUST ITSELF TO A CHANGING SOIL LEVEL.

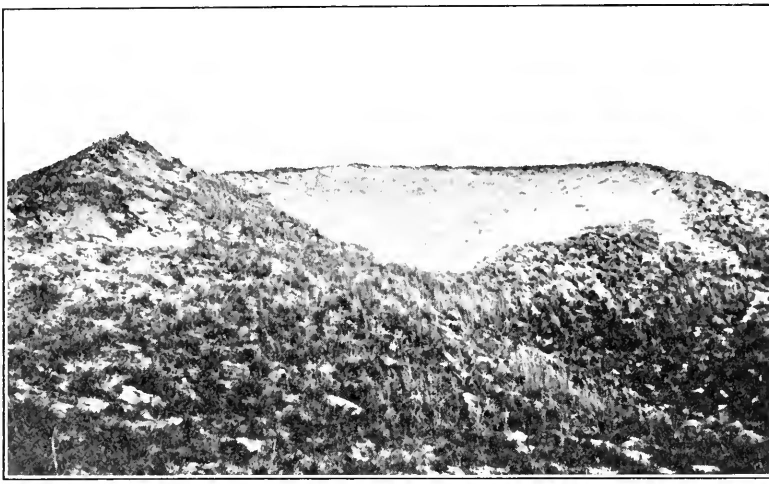


FIG. 5. A BLOW-OUT FROM THE WEST. Bunch-grasses on the outside, *Redfieldia* on the inside.

scattered individuals here and there, or may occasionally form rather dense communities: spiderwort (*Tradescantia virginica*), tufted hymenopappus (*Hymenopappus filifolius*), purple blazing star (*Lacinaria squarrosa*), lance-leaved psoralea (*Psoralea lanceolata*), western thistle (*Carduus plattensis*), rough sunflower (*Helianthus scaberrimus*), prickly poppy (*Argemone intermedia*), long-leaved milk vetch (*Phaca longifolia*), green milkweed (*Acerates viridiflora*), switch grass (*Panicum virgatum*), prairie pink (*Lygodesmia juncea*), Geyer's spunge (*Euphorbia geyeri*), yellow evening primrose (*Œnothera rombipetala*), sweet pea (*Lathyrus ornatus*), and hairy golden aster (*Chrysopsis villosa*). All of these plants occur as scattered individuals except the milk vetch and prairie pink, which are often gregarious. They all show striking anatomical characters that doubtless aid in their survival in such dry soils, exposed to such trying climatic conditions.

In addition to the grasses and the common herbaceous associates the vegetation of the upland is rich in species of low shrubs. In many restricted localities these under-shrubs compose the bulk of the vegetation and really rival the bunch-grasses in dominance. Among these low, much branched, woody plants, New Jersey tea (*Ceanothus ovatus*), Bessey's sand cherry (*Prunus Besseyi*), poison ivy (*Rhus radicans*), and the prairie clovers (*Kuhnistera purpurea, K. villosa,* and *K. alba*) are the commonest and most widely distributed. All of these plants are dwarfed, much branched shrubs often growing in communities. New Jersey tea is found most frequently near the tops of the hills on north facing slopes, where the dense, light

green patches from ten to seventy feet across contrast very greatly with the surrounding bunch-grass vegetation. Bessey's sand cherry is one of the most ubiquitous plants of the whole region. It is found in almost every site of the uplands and with its low, short twigs with tufts of glossy green leaves is seen springing from the sand on practically every side of every hill. Very frequently it forms extensive communities. The prairie clovers seldom form well-defined communities, but they occur as more or less scattered individuals, especially on the lower slopes of the hills adjacent to the larger valleys.

The most striking habitats of the uplands are the "blow-outs." Blow-outs are conical or rounded depressions of varying depth and diameter formed by the blowing of the sand and vegetation from certain spots on the upper slopes and crests of the hills. The rim of the more or less conical depression is sometimes almost circular but it is usually irregular with a general circular outline. Since the prevailing winds of the region are from the west, and since "blow-outs" are the direct products of wind action, these peculiar structures are mostly confined to the west sides of the hills. The greatest number occur on the northwest-facing slope, but they range in position from northwest to southwest, depending somewhat upon the shape of the hill concerned and its relation to the adjacent hills. Blow-outs do not occur on all hills, nor does a single hill show more than a single blow-out, as a rule.

On an exposed upper slope when the vegetation becomes broken or seriously depleted from any cause, the wind as it sweeps up the slope catches the sand and carries it over the crest of the hill a few yards farther away and deposits it upon the lee face of the hill. In this way

FIG. 6. A BLOW-OUT FROM THE EAST. The sand has been blown out of the crater on the other side. Bunch-grass in the foreground.

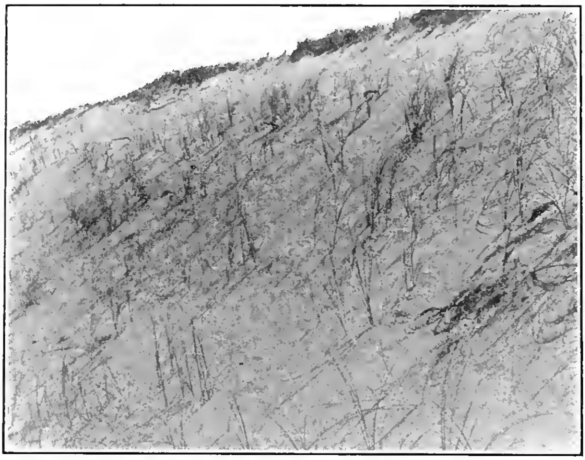


FIG. 7. DETAIL IN BLOW-OUT SHOWN IN FIG. 5. The only plant here is *Redfieldia flexuosa*.

as more and more sand is carried away and the up-rooted plants are swept on with the gale, the embryonic blow-out comes rapidly into existence. At this early stage it appears as an area of bare sand a few feet or yards across, over which the wind sweeps and continues to eat its way deeper and deeper into the sand. During this early stage the deep-seated roots of woody plants frequently appear strewn over the surface of the shallow depressions until the wind has finally eaten its way far below the point of penetration of the deepest rooted plants. At last the whole rounded or conical hill top is blown away and a deep crater is developed in its stead.

The two chief factors that enable the wind to begin this work of destruction are fire and over-grazing. Both factors frequently result in reducing the vegetation to a point below effective wind resistance and as soon as this is done, if the exposure be right, wind erosion begins. Nothing is quite so terrible as a prairie fire in paving the way for shifting sands and the development of blow-outs, since in such cases absolutely everything above the surface is destroyed. And so if cattle are allowed to run for too long a time over a given range the grasses are seriously reduced and the soil is tramped bare of plants for considerable distances, making it very readily possible for the wind to strike at the open sands. The effects of over-grazing are contrasted to a striking degree in the Sand Hills, where a fence separates the over-grazed pasture from the ungrazed range. Such sights have resulted in the enactment of grazing laws which naturally do not in all cases please the cattlemen, but they do usually protect the range and make it more stable.

When the young blow-out is no more than a foot in depth the sand begins to slide into the depression from the sides. This sand is blown

away and more continues to slide in, and in this manner the blow-out increases in area as well as in depth. These two processes continue for a number of years until, in many cases, the well-developed crater-form depression is blown out of the hill. Naturally with the increasing depth of the blow-out the direct force of the wind becomes considerably checked by the prominent rim of the crater. But peculiarly enough, as the wind strikes the farther slope of the blow-out a reverse current is developed which strikes beneath the rim and dips into the bottom of the crater. In this way a spiral wind movement is frequently developed and the wind reaches to the very bottom of the blow-out, which may now be fifty or more feet below the rim. This grinding action of the wind continues to loosen more sand at the sides, causing it to slip more and more into the bottom, where the wind catches it and hurls it up over the sloping interior surface of the blow-out and out over the rim. This action is quite appropriately called the "sand mill." The action of these spiral currents are conspicuous during rather low winds as well as on very windy days. Such activity is a very important factor in hollowing the blow-outs to the greater depths.

After many years of this sort of growth, blow-outs at the end of their maximum activity become enormous depressions with a rim sometimes 300 to 900 feet in circumference with sides of bare sand sloping inward at an angle of about 30 degrees to the bottom, which may be from 20 to 75 feet or more beneath the rim. In the western portion of the region where blow-outs are formed in rather low hills among the lakes the sand is removed from the interior until the water table is reached.

During the years of greatest blow-out activity plants fail absolutely to gain a foothold and establish themselves in the blow-out be-

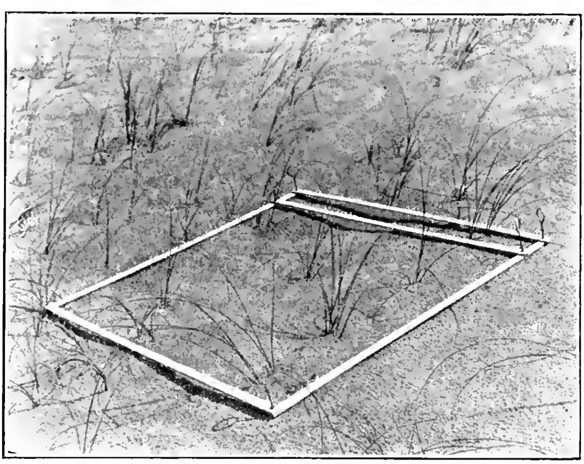


FIG. 8. A SQUARE METER QUADRAT ON THE SLOPE SHOWN IN FIG. 7.

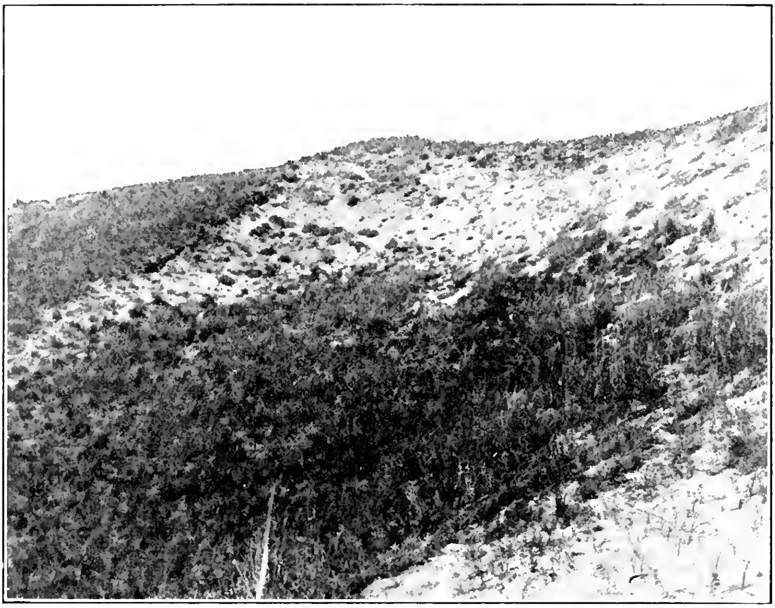


Fig. 9. A Late Stage in the Reclamation of a Blow-out; the bunch-grasses have now appeared and are creeping up the slope.

cause of the great exposure to wind and shifting sand. The combined action of a high wind, high soil temperature, excessive evaporation, and an unstable soil in the active blow-out, is a condition that plants can not survive. Sooner or later, however, because the blow-out has reached such a depth that the "sand mill" becomes ineffective and the sliding sand fails to reach the bottom, certain plants appear in the bare sand of the blow-out. From this time the terrible physical conditions begin to wane and the vegetation gradually creeps up from the bottom of the blow-out and slowly becomes the master of the situation. The decadence of the blow-out is traced in the development of the vegetation from these first successful invasions until the whole crater-like depression is claimed by the bunch-grasses and their common neighbors.

The first plants to become established in such places are certain grasses commonly called "blow-out grasses." The most important of these is Redfield's grass (*Redfieldia flexuosa*) which is almost always the very first pioneer in the reclamation of the blow-out. *Redfieldia* may be the only plant in such situations for many years. All during this time it is extending its area by undermining and binding the soil with its network of slender rhizomes. From these rhizomes there arise tufts of long, flexuous, narrow leaves gracefully nodding in the gentle breeze or lashing about like so many slender wires in the higher winds. Sometimes in a single windstorm the sand level about these tufts may

be reduced two inches or more, but seldom are the plants uprooted. It is to the rhizome habit of propagation that *Redfieldia* owes its success in thus so completely capturing the blow-out. The later invaders are also provided with this device, which certainly is the key to the whole situation.

After *Redfieldia* has once taken charge of the habitat other species soon begin to wander over the rim of the blow-out and to invade the area occupied by the first blow-out pioneer. Among the first of these early invaders we must number the spiny blow-out grass (*Muhlenbergia pungens*), sand grass (*Calamovilfa longifolia*), and the hair-like eragrostis (*Eragrostis trichodes*). From the appearance of these grasses the decline of the blow-out is rather rapid. As these various species wander up the steep sides, and the force of the wind striking upon the upper slopes is reduced and the sand held from blowing, other species wander in from the bunch-grass association. If these new plants are properly provided with a rhizome device like that of their predecessors they soon begin to weave themselves into the now conspicuous blow-out association. The plants that most commonly gain entrance soon after the grasses have become well established are prairie pink (*Lygodesmia juncea*), small-flowered psoralea (*Psoralea micrantha*), long-leaved milk vetch (*Phaca longifolia*), and the hairy golden aster (*Chrysopsis villosa*). Indeed, some of these species may get a start in the declining blow-out almost as soon as *Redfieldia*.

In this manner the effect of blow-out conditions are finally so far removed that the bunch-grasses enter and take possession of the area so well prepared by the pioneers in the succession. It is almost pathetic to find that *Redfieldia*, the first plant to appear in the blow-out

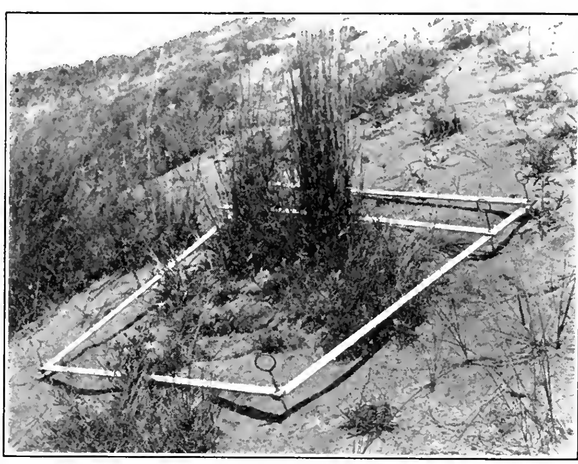


FIG. 10. A SQUARE METER QUADRAT IN THE BLOW-OUT SHOWN IN FIG. 9. The bunch-grass is now conspicuous with a few tufts of *Redfieldia* at the right.

and the plant of greatest importance in its reclamation, after struggling against severe physical conditions for so many years is also the first to disappear. It fails in the competition with the later arrivals and is then forced to find other blow-outs in which it may continue its great work. With the development of the bunch-grasses and the resulting competition all of the blow-out grasses disappear, and then with the incoming of the characteristic members of the bunch-grass association, the change from blow-out to hillside is complete. The only indications of the former history of the place are seen in the grassed-over crater which frequently persists as a characteristic form, and perhaps a few straggling clumps of the blow-out grasses lingering in the near vicinity.

On the lower slopes of the hills and in the valleys many new species are encountered as the bunch-grasses of the uplands are left behind. Rather low down on the north-facing slopes one frequently finds conspicuous associations of willows (*Salix humilis*) and dogwoods (*Cornus stolonifera*). The prairie shoestring (*Amorpha canescens*) also gives tone to the lower slopes in many places by its typical low-branching, ashen-colored plants closely aggregated. Even the taller shoestring (*Amorpha fruticosa*) occasionally wanders from its usual habitat in the moist valley and is found on north slopes among the willows and dogwoods. The presence of such plants always indicates a higher percentage of soil moisture quite near the surface than is found typically in the bunch-grass association. The explanation of this phenomenon is not hard to find, because such associations and such soil conditions almost always mark an outcrop of clay or other impermeable rock strata which lead the ground water from under the hills in a horizontal direction until it is brought near the surface. If the clay or rock does not actually appear on the surface it is usually found a few feet beneath, so that the effect is practically as has been given. The water is frequently so abundant in such situations that it seeps out and collects in cow tracks and other holes in the more tenacious soil. This results in the development of a soggy soil where one finds such moisture-loving plants as marsh mint (*Stachys palustris*), Venus's looking-glass (*Specularia perfoliata*), Solomon's seal (*Vagnera stellata*), heal all (*Prunella vulgaris*), long-bracted orchid (*Cœloglossum bracteatum*), rush (*Juncus balticus*), liverwort (*Marchantia polymorpha*), mosses (*Bryum* sp.), etc. The cow tracks are frequently filled with filamentous algæ and free-swimming animals such as *Euglena*.

The willow thickets, although quite striking structures on the lower slopes, are still well within the bunch-grass association. But as one gets down into the valleys proper the bunch-grasses, and also many of their associates, are left behind. There are two quite distinct types of valleys in the Sand Hills. The dry valleys are relatively short and narrow and with a good covering of grasses which often form a close

sod, but with no standing water. The well-developed sod is a condition that causes the vegetation of the valleys to be quite distinct in appearance from that of the uplands, with the tufted appearance of the bunch-grass association. Such dry valleys are very common throughout the southern portion of the Sand Hills. They yield an abundant crop of

FIG. 11. A DEEP BLOW-OUT; *Redfieldia* on the slopes.

fine hay during moist seasons and always afford very fine forage because of the presence of buffalo grass (*Bulbilis dactyloides*), and grama grass (*Bouteloua oligostachya*) in considerable quantity. The soil of these valleys is not so sandy as the uplands. This with the water table nearer the surface makes possible the culture of certain agricultural crops, if the proper care is taken to prevent the soil from blowing. When the sod is broken in a dry valley where a considerable area of nearly flat soil

is exposed to the wind, the blowing soil frequently prevents the growth of field crops or any other plants.

The flora of the dry valleys is very similar to that of the prairie regions of the state, being especially rich in grasses. The principal widely distributed plants of the dry valley are: switch grass (*Panicum virgatum*), wheat grass (*Agropyrum pseudo-repens*), blue joint grass (*Calamagrostis canadensis*), wild rye grass (*Elymus canadensis*), red top (*Agrostis alba*), tickle grass (*Agrostis hiemalis*), rattlesnake grass (*Panicularia americana*), and a number of sedges (*Carex trichocarpa, C. filiformis,* etc.). All of these species are valuable forage plants and they are all included in most of the hay that is put up from the valleys. Besides these economic plants there are many other herbaceous members of the prairie flora that have wandered into the Sand Hills and have found congenial homes in these dry valleys.

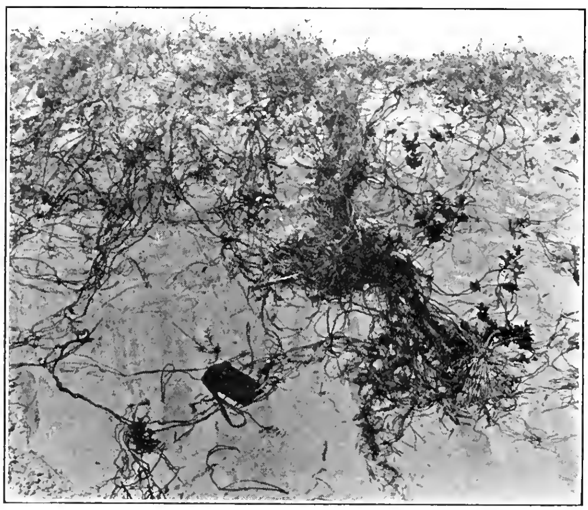


FIG. 12. THE RIM OF A BLOW-OUT WITH THE FRINGE OF ROOTS AND THE SLIPPING SANDS.

The river flats properly belong to the dry valley type, since here we find a soil free from surface water and with all of the above species of plants often growing in profusion. These low flat areas extend from the banks of the river back sometimes several hundred yards to the bases of the hills. These flats or "benches" are well developed along the Middle Loup River. The river winds across the flats in a very irregular course, sometimes cutting close to the hills on one side and then shooting across to the hills on the opposite side of the flat. On these flats and along the bank close to the stream occur the most of the trees of the region. Thickets of plum (*Prunus americana*), and cherry

(*Prunus melanocarpa*), several acres in extent are common in such places. Green ash (*Fraxinus lanceolata*), cottonwood (*Populus sargentii*) and willow (*Salix nigra, S. longifolia*) also thrive on this soil. In the plum thickets near the river the vegetation often becomes so dense that it is almost impossible to penetrate to the river's edge. The soil in these places is very rich and moist, so that many species of the shade plants of moist rich woodlands find in such thickets very favorable conditions. On the open areas of the river flats buffalo grass and grama grass constitute the best forage known in the Sand Hills. These low, sod-forming grasses are especially valuable as winter forage.

Wet valleys are very common in the northern portion of the Sand Hill region, where the valleys are usually broad and long. The water table is near the surface in these valleys, so that the soil in many places is very wet and swampy. There are in this portion of the hills many gradations from the moderately dry hay valley through wet meadow valleys to valleys with large ponds or lakes. Hundreds of lakes occur in such situations throughout the northern half of the Sand Hill region. There have been two general kinds of wet meadows distinguished.[5] The rush-meadow type is characterized by the presence of a number of rushes (*Juncus tenuis* and *J. nodosus*), and bulrush (*Scirpus atrovirens* and *S. americanus*). With these occur a few moisture-loving grasses, such as lowland rattlesnake grass (*Panicularia nervata*) and whorl grass (*Catabrosa aquatica*). In the wet valleys along the Loup River and in wet places on the river flats a second type of wet meadow is seen in the fern meadow. Shield fern (*Dryopteris thelypteris*) and the sensitive fern (*Onoclea sensibilis*) often occur in great quantities in such places with a mixture of willow herb (*Epilobium lineare*), St. John's wort (*Hypericum virginicum*), goose grass (*Galium trifidum*) and marsh bellflower (*Campanula aparinoides*). Frequently the ferns are so dense as to cause considerable difficulty in walking through this type of wet meadow.

There are two kinds of lakes in the Sand Hills, depending upon the amount of dissolved substances in the water, alkali lakes and fresh water lakes. It has been found that the alkalinity of the lakes varies between rather great extremes, even the freshest of the fresh-water lakes being somewhat saline. Whatever may be the cause of this gradient in alkalinity, it is an obvious fact that the degree of alkalinity exerts a very powerful influence upon the vegetation. Studies are now in progress that will probably throw considerable light upon the power of certain species of plants and animals to adjust themselves to this varying chemical relation. In many of the more strongly saline waters scarcely any vegetation appears, although the beach may be well clothed with

[5] Pound and Clements.

rushes, sedges and salt-grasses. Frequently even the beach, many feet back from the water's edge, is so thoroughly impregnated with salts that they crystallize and form a white crust over the surface. This results in an absolutely barren zone. Back of that portion of the beach washed by the waves the salt-enduring plants develop very copiously. The salt-grass (*Distichlis spicata*) is usually controlling in such places where the low plants develop a very close tenacious sod. Beyond the belt of salt-grasses the taller stems of other grasses, sedges and rushes make up another distinct zone which may completely encircle the pond or lake. These plants are very dark green, so that the belts of vegetation about the saline lakes stand in marked contrast to the duller tones of the surrounding hills. Still farther back beyond the zone of tall plants the shore vegetation of the saline lake passes either abruptly or gradually into the typical wet meadow vegetation.

The appearance of the fresh-water lakes is quite different. First of all there is usually a wealth of submerged or half-submerged plants. Some of these lakes are literally filled with great masses of pondweeds (*Potamogeton, several species*), and the water milfoil (*Myriophyllum spicatum*). The bottom, in the shallower portions of such lakes, is covered with a carpet of stonewort (*Chara fœtida*, etc.), while the stems of the submerged flowering plants are richly coated with algæ of many kinds. In late summer certain of these algæ become broken away from their substrata and float about on the surface of the water. During high winds at this time great quantities of these, such as the net sack (*Clathrocystis æruginosa*), are washed on the beach in yellow green splashes. So there are many very interesting animals in the fresh-water lakes, a sponge being one of the common forms.

The white, encrusted beach is absent from the fresh-water lakes, as also are the belts of salt-enduring plants. The commonest marginal plant here is the great bulrush (*Scirpus lacustris*). Frequently this is the only plant between the bunch-grass association of the hills and the open water of the lake. Sometimes other species such as cat tail (*Typha latifolia*), and the giant reed grass (*Phragmites phragmites*) occur in mixture with the bulrush, or these may now and then form separate belts. Wild rice grass (*Zizania aquatica*) is a common marginal or shallow-water inhabitant of many of the lakes. This plant is about as tall as the bulrush, but because of its leafy stems it often forms much denser stands in the shallow water. When the seed is ripe every bed of wild rice is a Mecca for thousands of water fowl that live in the vicinity of the lakes. Wild ducks become so thick at times in these rich feeding grounds that the noise they make reminds one of an over-stocked barnyard.

The lakes range in size from small ponds to bodies of water one and

one half miles wide by five miles long. They vary in depth from four feet to probably about twenty-five feet. In many of the fresh water lakes the vegetation is encroaching upon the water, so that in time all of the lakes will have disappeared and wet meadows remain. The wet meadows of to-day show this sort of an origin very plainly. Many stages in lake eradication by invading vegetation may be seen in these lake regions. Some lakes are quite free from submerged aquatic plants; others quite free from bulrushes or wild rice; others show belts of these plants about the shore; in others the bulrushes have begun to wander

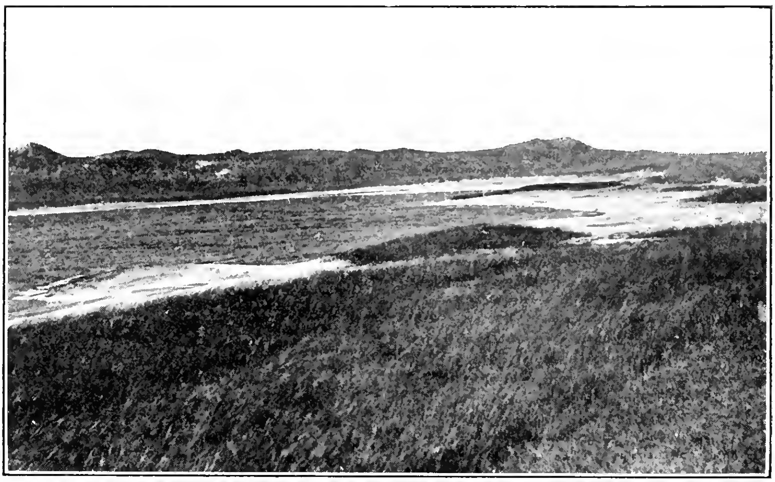


FIG. 13. SOME OF THE LAKES ARE SO STRONGLY ALKALINE THAT THE SALTS COAT THE BEACH WITH A WHITE CRUST.

into the deeper water, and in still older lakes the water can not be seen because of the complete occupation by the bulrushes and other vegetation. The bulrush is the commonest pioneer in this succession, and it is well fitted for this particular process. Oddly enough it is by the possession of the rhizome type of propagation, the very same character that fits *Redfieldia* for capturing the blow-out, that the bulrush is enabled to thus encroach upon the open water and finally to capture the lake. In the one case we have a species successfully eradicating a very dry, unstable habitat and in the other case a different species eradicating a very wet, stable habitat by identically the same means. The creeping rhizomes of the bulrush keep reaching into deeper water as the lake bottom is built up until other species are enabled to gain a hold back of the rushes. Thus other species follow in the wake of the bulrushes, and then come the common wet meadow species. At last the water is gone, the aquatic plants are gone, the bulrushes are gone, and the wet meadow plants have full possession of the former lake area,

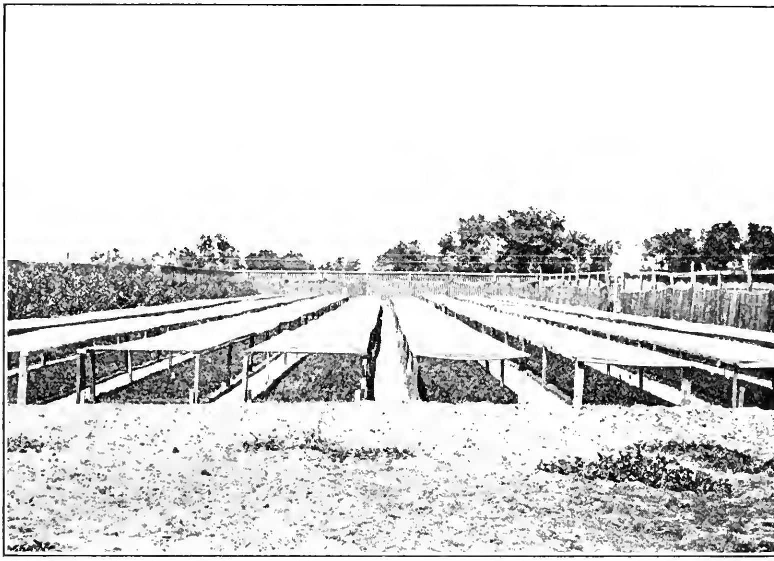


FIG. 14. A SECTION OF WESTERN YELLOW PINE IN THE GOVERNMENT FOREST NURSERY AT HALSEY.

and perhaps the stockman now mows his hay where once was open water.

The soil and climatic conditions over the Sand Hills as a whole are such as to fit this region in a peculiar manner for the grazing of immense herds of cattle. It is from the pursuit of this great industry that the region must always furnish its greatest returns. Thousands of cattle are annually shipped to the eastern markets from the Sand Hills. It is truly amazing to the "newcomer" to see how well the stock does upon what seems to be very meager forage. But with a well-kept range for the summer and plenty of hay for the winter the cattleman realizes a neat return from his labors. Those inhabitants who are so fortunate as to possess fertile valley land in addition to their upland range have made considerable progress along agricultural lines. The soil in many valleys is sufficiently fertile for the production of almost all of the common field and garden crops. Naturally because of the low acreage of agricultural land this industry will never reach great proportions. Alfalfa is destined to become the most important single crop in the Sand Hills. There are already many very good fields of this valuable plant. It is especially fitted to the soil conditions of many valleys, and when once established it resists the fury of the wind in a very encouraging manner. The success that has already been obtained by the early sowings should encourage other settlers to try it out very carefully.

Enormous crops of garden vegetables may be obtained from the river flats if the gardens are so situated that the land may be irrigated from

the river—and this is possible in a great many places. There are hundreds of acres on flats along the Loup River that could be made to yield high returns from truck crops. A small irrigation plant would cost but little, and the luxury of fresh vegetables would gladden the whole life of many a Sand Hill housewife who too often "digs" or "pulls" all of her garden truck from cans.

Much has been said and written about the possibility of covering the Sand Hills with trees. About ten years ago the U. S. Department of Agriculture, acting upon a suggestion from Professor Charles E. Bessey, made a preliminary examination of the region to determine if the conditions warranted an attempt at forestation. The examination resulted in the setting aside of about 80,000 acres in the worst portion of the hills between the Middle Loup and Dismal rivers as a national forest. The flats along the Loup afforded very favorable sites for the forest nursery, and, since it was thought best to raise the stock in the hills, a permanent station was established on the south side of the Loup about two miles west of Halsey in Thomas County.

In the spring of 1903 small jack pines were imported from Minnesota and these were set out on the hills. During this summer the forest nursery was started and from that time the Forest Service has continued to raise its own stock in its own nursery and every spring to plant

FIG. 15. THE PINE TREES DO BETTER IN THE MORE OPEN SAND THAN IN COMPETITION WITH THE GRASSES.

thousands of trees upon the hills. Naturally there have been mistakes and failures, but after almost a decade of active operations on the Dismal River National Forest one can not but marvel at the results obtained, if he is at all familiar with the extreme natural conditions that the government's experts have attempted to meet. The pine trees that were planted in 1903 are now about twelve feet in height and four inches in diameter. The bunch-grasses have been shaded out and a fine carpet of pine needles is beginning to accumulate beneath the green crowns of this young Sand Hill forest. So also, as I was able to demonstrate during the past summer, the temperature of air and soil, the humidity and evaporation, and the movements of the air in the vicinity of this plantation have been profoundly modified in comparison to those conditions in the bunch-grass association that completely surrounds these plantations. It is a most interesting and significant fact that the trees have adjusted themselves more readily to the fury of the wind on the hilltops and even in the blow-outs than to the struggle with other vegetation in the moister and more protected situations. Mr. Pierce, the supervisor of the Nebraska National Forest, told me in October that eighty per cent. of the trees planted in 1911 had passed through the summer drought and were making a brave effort to become permanent fixtures in the Sand Hill landscape.

The forest nursery established in 1903 has been enlarged from time to time until now it covers about five acres. When all of the seed beds are in use the nursery can care for about four million seedlings and two million transplants. The care of the delicate seedlings requires a great amount of skill and a large force of men in order that they may be kept free from disease and develop perfectly for the planting on the hills.

While it will be many years in the future before any return will be realized from this enormous experiment of the government's, yet the success of the first decade certainly warrants the continuation of the experiment. It is hoped that at some distant time acres of flourishing pine trees will grace many of the hills now so completely dominated by the bunch-grass.

The people of the Sand Hills are a hale and hardy lot. Their life is a rather hard one, even if they take advantage of every comfort possible for them. Many of them were lured by the roseate stories of the early "boomers" and came to the region from the east years ago. They found that the glowing tales of the wealth of the region were mostly florid falsehoods and that they were in a strange land whose productivity was not at all apparent and the rigors of whose climate were at times most severe. Many of these early homesteaders used up all of their capital in getting into the Sand Hills. Once there their disappoint-

ment was keen, but they could not return. They settled on the one-hundred-and-sixty-acre homestead, and during the first winter lived in a miserable, unhomelike dugout. In such a condition, poorly clad, without coal or other fuel in quantity, they braved that first terrible winter with its icy blizzards, the spring coming barely in time to save

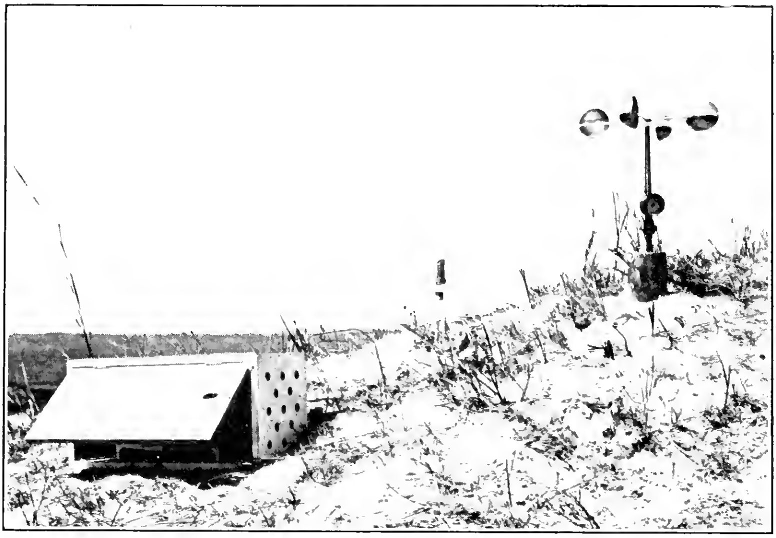


FIG. 16. INSTRUMENTS FOR THE DETERMINATION OF WIND VELOCITY, EVAPORATION, RELATIVE HUMIDITY AND TEMPERATURE.

them from an agonizing death. The next summer perhaps they built a small sod house into which were moved the few belongings, and then they began to map out plans for their future existence. There were neighbors in equally straitened circumstances, but after a while it was found possible to buy a few cattle and in this way a permanent livelihood was assured, and the foundations were laid for what is now one of the most important industries of the state.

The population of the Sand Hills is widely scattered. One may ride for twenty or thirty miles in almost any part of the hills and not see more than one or two houses, and frequently in such a ride he may not see a single home or meet a single person. The lack of human associates together with the monotony of the landscape and the slow routine of the lonesome day, the parching winds of summer, the call of the range, and the crimping blasts of winter, has left a telling imprint upon the homesteader and has made him a grizzled, fearless man. Far from the influence of the laws and the morals of civilization, he constructed his own statutes and his own code of morals. There were few entries here, but woe to him of the hills who lived not the life of an open book.

"A square deal for all" was the motto that the knights of this grassy kingdom wrote across their breasts. If a horse disappeared from the corral a hurried call was sent forth and a small mounted committee was soon scouring the hills. If the wrong man was found riding away astride the missing animal, he was jerked down, tried before this quickly constructed bunch-grass court, found guilty of horse stealing and was speedily strung up to a tree with a lariat rope, long before a single juryman could be summoned in a region possessed of a "higher standard of

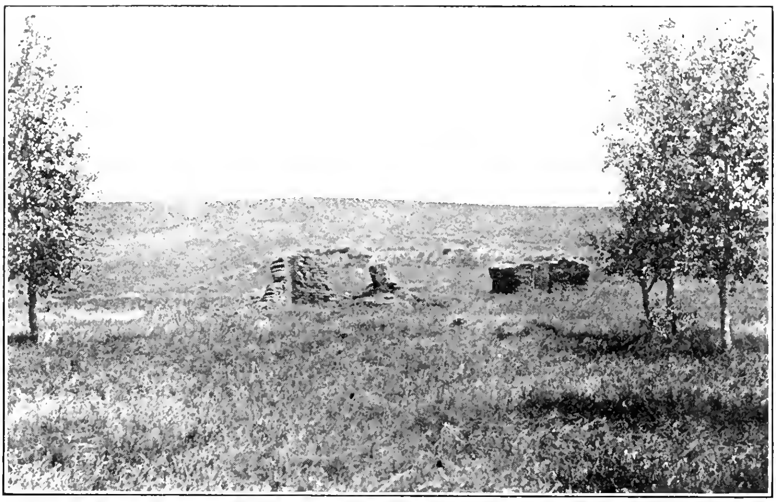


Fig. 17. The Deserted "Soddy" is Common in the Sand Hills.

ethics and a solemn regard for the law." Such was justice on the range, especially in the earlier days. Even in this late day the dove of peace does not nest in all the nooks of this great sand-hill domain. There is romance and chivalry of the real western sort in abundance. Only a few weeks ago four stalwart sons of the hills were sent to the state prison for life because of a deed that they thought was merely chivalrous. They went to the ranch house of a neighbor one night, took him from his bed, threw a rope over his head and pulled him up to a telephone pole. They had not intended to take the man's life, but simply sought to intimidate him and cause him to leave the country. He had made certain threats unbecoming to an inhabitant of the hills. He was allowed to dangle at the end of the lariat from the telephone pole too long, and as a consequence the four young men are in prison for the rest of their days.

From these statements the reader must not infer that life in the Sand Hills is dangerous or even uncongenial because of man's relation to his fellows. Naturally these people have individual rights which they

will protect with their lives, but to one who "lives in the open," no truer or more loyal friend can be found than in these rough men of the hills. Frugal, but hospitable to the extreme, they take great pleasure in the entertainment, in their humble way, of strangers who may chance among them.

Many of the homesteaders in this region after struggling along for a number of years, often facing death through cold or starvation, were compelled to relinquish their claims and leave the hills. So to-day one may find in many places the old dilapidated "soddy" and the scrubby, straggling timber claims of those who gave up the fight. On the other hand, many of those who managed to stay in the region have prospered. The sod shanty was for many years the characteristic habitation of the homesteader's family. This home was added to from time to time until a rather low, three- or four-roomed house of sod with plastered walls afforded much more comfort than the old conditions. At first the roof was also made of sod, but in later years the board or tar-paper roof has been substituted for the leaky sod. Those who have gone into the hills in the past few years and have taken claims under the Kincaid act have commonly built shacks of rough boards. Many of the older residents of the Sand Hills have lived for a number of years in very comfortable frame houses with most of the conveniences of the common farm house. Even the cement block has invaded the hills, and now there are numerous ranches with cement-block homes and round about the many other well-constructed buildings of the up-to-date ranch. Thus the development of the civilization and the architecture of the Sand Hills has passed through a number of periods in many ways as interesting and as remarkable as the evolution of the landscape and the vegetation of this great pasture domain.

LOWER DELTA OF THE MISSISSIPPI RIVER.
SHOWING MUD LUMPS AT MOUTHES OF PASSES.
Reduced from U.S. Coast Survey Sheet No. 194
Soundings in feet

5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
Statute Miles

A NEW DEVELOPMENT IN THE MISSISSIPPI DELTA

By Professor E. W. HILGARD
UNIVERSITY OF CALIFORNIA

Introduction

In 1867 the writer was commissioned by the Smithsonian Institution to determine, if possible, the geological age and mode of formation of the rock salt deposit on Petite Anse Island, Louisiana. This involved, of course, a general examination of the coast formations of Louisiana, and among them, of the Passes of the Mississippi, and of the puzzling phenomena of "mudlump" upheaval in the Passes, which, at times, seriously obstructed commerce, but the origin of which remained a matter of conjecture. It had, to some extent, been investigated by Sir Charles Lyell (1858) and is commented upon in the tenth edition of his "Elements of Geology"; it was also conjecturally discussed by General A. A. Humphreys and other engineers connected with the Mississippi River Commission. My results, so far as the salt deposit is concerned, were published as Memoir No. 248 of the Smithsonian Institution: while the full report of my investigations of the Mississippi mouths and the mudlumps was published in the *American Journal of Science* in 1871–72.

As this work and its publication dates back so many years, and the latest publications on American geology and hydrography have wholly omitted any mention of it; and since a new phase of the subject has lately arisen confirmative of the views expressed and forecast made by me in 1872, it seems appropriate to recall that work to mind, and direct attention to the unfortunate fulfilment of a former prediction.

The Lower Mississippi Delta not a Normal One

The bird-foot shape of the lower Mississippi delta, with deep embayments in between, is unexampled in any other large river delta in the world. The bays between the delta-fingers ("Passes") are being very slowly shallowed, chiefly by wave and tidal action from the Gulf, carrying in the bar sands; *and only subordinately by river overflow.* The river in this lower delta region is for 50 miles below Fort Jackson bordered by narrow banks of unyielding gray clay, between which is carried the entire volume of the river through the narrow-banked "Neck," until it reaches a common point of divergence, the "Head of the Passes," whence similarly narrow-banked channels diverge, unbranched, in bird-foot form. (See the map accompanying this paper.)

The usual shape of a *normal* delta is a convex protrusion beyond the main shore-line, with usually slight protrusions at the mouths of the distributaries; as can be seen by an inspection of the maps of the deltas of any of the larger rivers, such as the Nile, Ganges, Brahmaputra, Danube, Volga, Lena and others. Within the delta-areas of these streams, large and small distributaries form a complex network, frequently changing at times of high water. No such changes are shown by the narrow-banked, diverging arms of the lower Mississippi delta, which steadily advance into the Gulf singly, and without any permanent distributaries being formed. The only approach to the form and structure of an ordinary delta occurs about three miles above the Head of the Passes, on the east side, where small and shallow channels connect with the main river through Cubit's Gap, a shallow lateral outlet.

Notwithstanding these facts, the Mississippi delta is figured in the latest edition of Chamberlin and Salisbury's extended work on geology, apparently as an example of a "*normal*" delta, and its formation is somewhat elaborately, but unconvincingly explained on the basis of the formation of the ordinary river deltas. The explanations do not, unfortunately, fit the facts as observable by any one examining the banks of the Mississippi Passes; nor is any mention whatever made of the existence and formation of the "mudlumps," which have proved of such vital importance to the commerce passing through the mouths of the Mississippi, that they have been called the "evil geniuses of the Passes."

Mudlumps

Considering that these mudlumps have for many years been known to, and discussed by pilots, navigators and United States engineers, and have been somewhat elaborately treated of by Lyell many years ago, it is remarkable that their existence, and the part they have so obviously played in the régime of the Mississippi Passes, should have been wholly ignored by writers on general geology, and even in the standard work of Russell on the "Rivers of the United States."

As my detailed investigation of the subject, made in 1867, is not even mentioned among the references given by Chamberlin and Salisbury, it seems proper to recapitulate that investigation in print, especially since recent events in the delta seem to have strikingly confirmed my results.

The Port Hudson Clay ("Blue Delta Clay" of former Writers)

The investigations of Humphreys and Abbott had established the fact that the sands and silts of the true Mississippi delta, at least from Baton Rouge to the mouths, are underlaid at comparatively shallow depths by a stratum of blue clay, 10 to 20 feet in thickness, practically impervious to water, and almost inerodable by water alone. This is

called the "blue delta clay" by Humphreys and Abbott; it will here be called the Port Hudson Clay, because it is entirely independent of the modern delta formation built up by the river.

In this stratum, when exposed in-shore or in shallow water, there frequently appear stumps of the deciduous cypress, suggesting that in former geological times a cypress swamp extended out gulfward, perhaps to the deep-water line at the edge of the continental shelf.[1] Beneath this Port Hudson clay stratum lie formations materially different, and of such a character, both physical and biological, as clearly proves them to be not river alluvium, but of marine, brackish and paludal origin. But these formations, as well as the Port Hudson Clay, have nothing to do with the present problems of the delta, beyond serving as the floor on which it is built forward. The depth of the sands and silts of the true delta is practically from thirty to forty feet, and rarely reaches above sixty feet. That so great a river should show so small a depth of alluvium, when compared with such rivers as the Nile, Ganges, Hoangho and others, at first appears incredible; but it becomes intelligible when considered in connection with the existence of the underlying Port Hudson clay stratum, and the extraordinarily rapid extension of the mouth of the river towards the Gulf; the advance of the bar at the mouth of the Southwest Pass being, at the time mentioned, about 340 feet per annum. That this advance, however, is not made by the usual process of delta formation, is clearly shown on the accompanying map of the mouths of the Mississippi, and the "normal" delta of the Volga.

Continental Shelf

As is well known, a continental shelf, covered by a comparatively shallow depth of water, runs out for about thirty miles beyond the present mouths of the Mississippi River, then breaks off into the deep waters of the Gulf. The original surface stratum of this shelf is the Port Hudson clay (the "blue delta clay" of Humphreys and Abbott); but it is now coming to be gradually covered with the delta deposits of river sediment; and it would be natural to connect the shallow-lying shelf with the unusually rapid advance of the river mouths.

It is not easy to see at first sight why even the existence of the Port Hudson clay stratum should interfere with the ordinary, merely con-

[1] In view of the many phenomena indicating that the present course of the Mississippi River is comparatively young, and that in times not far remote its waters flowed toward the Arctic Ocean, as contended by Professor G. H. Tight, such a condition of things would simply indicate a temporary cessation of an oscillation which, taking into consideration the deep submerged channels of western Louisiana and the present elevation of the Loess hills of Mississippi and Louisiana above the level of the river, as discussed by me (*Am. Journ. Sc.*, Vol. 48, November, 1869, p. 335) would amount to more than 800 feet.

vex form of the delta protrusion; nor why there should be the sudden diversion of the several main distributaries from one permanent point, viz., the Head of the Passes, and a failure of the Passes themselves to give out numerous minor distributaries, as is the case in all other known deltas.

Moreover, the existence of the "Neck," a single, narrow-banked channel carrying the main river from below Forts Jackson and St. Philip to the Head of the Passes without breaking through the narrow embankment into Grand and Bird Island Bays, is precisely analogous to the fingers of the lower delta.

Mudlump Clay

Even a cursory examination of the material causing this division and obstinately resisting the impact of the main current of the river at the Head of the Passes, shows that it is wholly distinct in character from the ordinary sandy and silty river sediment, and very different also from the Port Hudson clay; being a compact, impervious gray clay, and corresponding exactly to the material constituting the mudlumps. So long as it remains submerged or fully wetted, this clay resists erosion to a remarkable degree.

As we descend either of the Passes, an examination of their banks shows that these are formed of this same gray clay, and not of sandy or silty river deposit, which usually covers the clay only to the depth of a few feet. Hence, even a rise of the river does not wash out such lateral channels as Chamberlin and Salisbury speak of, connecting the river current with the adjacent bays. Even where such channels exist they have occasionally to be dug out by hunters or fishermen in order to reach the intervening bays, as they tend to fill up with the débris of mudlumps, and with river deposit. As we approach the mouths of the Passes, the banks are found to consist of small islets with small, shallow channels between, which, however, are also being rapidly filled in, progressively, partly by river deposit, but chiefly by disintegrated clay of the mudlump masses that have been raised above the water level. For when this clay of which the mudlump masses consist has been exposed to repeated partial drying and wetting, it crumbles into a loose mass, which is washed by rains into the shallow channels intervening between the mudlump islets and there settles into a mass very resistant to erosion.

Active Mudlump Cones

Still farther downstream we come, *in all but the South Pass,* to mudlump islets obstructing the channel, *historically known to have been upheaved from the river bottom,* and frequently exhibiting low cones from the apices of which there is a steady flow of semi-liquid mud,

accompanied by an occasional bubble of combustible gas. Remnants of such active mudlump cones have successively obstructed the Pass à l'Outre, its branch, the Northeast Pass, and the Southwest Pass. Rod soundings in active mudlump craters have reached a depth of 24 feet, but no solid bottom.

On measuring the proportion between the volume of gas and mud, I found the former to range from about one twenty-fifth to one thirtieth of the mud flow; the uniformity of which clearly indicates a steady pressure or *vis-a-tergo*. The mud flow, according to the universal testimony of river pilots, varies with the stages of the river, becoming much more lively at times of flood. Clearly, the gas is a wholly subordinate feature and not the *cause* of the mud flow; as has already been stated by Sir Charles Lyell. The latter attributed the ascent of the mud to the pressure of the sands and silts of the bar at the mouth of the Pass upon a *mud stratum lying beneath them and under the bed of the river,* the origin of which he, however, did not try to explain, but which is now to be considered.

Mud Layer Formed by Flocculation Beyond the Bar

My investigations of the peculiarities of colloidal clay, begun about 1869, led me to conjecture that the stratum of liquid mud was due to the precipitation of such clay from its diffusion in the turbid clay-water passing over the bar, by intermixture with the saline sea water; and that a layer of gelatinous, semi-fluid mud should, therefore, be found to seaward of the bar. That such is actually the case was proved by numerous reports received from pilots of sea-going vessels, who stated that at varying distances outside of the bar the sounding-lead begins to sink more slowly before it comes to a final stop on solid sea bottom, usually the Port Hudson clay. I could not obtain any definite estimate of the depth of the mudlayer, but the pilots said it might be from five to fifteen feet, according to the distance out from the bar.

I have, unfortunately, been unable to obtain an authentic sample of this mud from outside the bar. But of its existence there can be no doubt, and the huge scale upon which clay precipitation by flocculation occurs at mouths of all turbid streams emptying into the sea or saline basins, clearly shows that flocculation is certainly not the "limited and obscure" phenomenon that Chamberlin and Salisbury declare it to be ("Geology," Vol. I., p. 360). As the bar is built forward, the river sands and silts are spread on the mud stratum, so as to bury it under a broad cover. There would then tend to form on the surface of the mud stratum, by upward filtration, a thin but compact crust of tough clay constituting the bed of the river beneath the sands and silts which

are continually shifting with the current. Under this crust, however, the semifluid mud-stratum would remain, and would also underlie the river channel inside of the bar, on both sides of the channel, and farther upstream to an unknown distance, in one connected layer; and would be subjected everywhere to the pressure of the marshes and overflow materials.

Mechanism of Mudlump Upheaval

Taking the existence of this semi-fluid mud-stratum resting upon the Port Hudson clay and buried by the delta sands and silts throughout the lower delta, for granted, the mechanism of mudlump upheaval at once suggests itself; for the rapid advance of the heavy and extended load of river sands and silts of the bar over the mud stratum would not permit the escape of the slow-moving mud to seaward.

A striking confirmation of the presumption that the pressure on the mudlayer is exerted by the accumulation of sediment and vegetation in the marshes, and of the existence of the mud-layer itself even under the older marsh formation, is the occurrence of a large mudlump-cone in full activity in 1867, in the marsh seven miles above the mouth of the Southwest Pass, and between it and West Bay. From the Pass, it appeared as a slightly irregular conical hill, which, judging from the extent to which it projected above the highest reeds, was about 18 to 20 feet in height. A glittering mud stream on the south slope could readily be distinguished by the field glass. The lump was inaccessible at the time of my visit, but had previously been fully described from a personal visit by pilot Ben Morgan.

Mudlumps commonly arise in a channel or pass *immediately inside of the steep upstream slope of the bar,* in or alongside of the main current, where the depth is greatest, and where the bottom therefore can most readily yield. Soundings show that (doubtless owing to the impact and consequent scooping action of the river current as it is forced to ascend to the crest of the bar) there is nearly always a maximum depth just at that point, in the course of the main channel. This would seem to mean that as the weight of the superincumbent river sands and silts is thus relieved, the pressure of the great area of marshes lying upstream, of the delta deposits on either side, and to some extent, perhaps, the pressure of the bar itself, causes the upheaval of the river bed and in many, though not in all, cases produces an extrusion of the semi-fluid mud which is but slowly washed away by the current. The vents are formed near the water surface at first, but are then built up from the outflowing mud, which partly consolidates by loss of water, until small mud volcanoes, rising usually from three to four, but sometimes as much as twelve feet above the water surface, are formed.

A comparison of the mud ejected with that forming the narrow banks of resistant clay bordering the Passes, as above outlined, and also the same resistant clay banks at the Head of the Passes which cause their divergence, shows the materials to be undistinguishable. The conclusion is inevitable that the entire bird-foot delta at least, and doubtless also the narrow Neck in which the main river flows below Forts Jackson and St. Philip, are the outcome of the formation and destruction of mudlumps as the river progressed; and that these clay banks constitute the normal mode of progression of the emerged portion of the lower delta.

The extraordinary resistance of the mudlump clay, when once consolidated in the channel banks, to erosion by water, serves, together with the somewhat similar characteristics of the underlying Port Hudson clay, to explain the exceptional form of the lower delta of the Mississippi.

I should add that a microscopic, physical and chemical examination of the mudlump mud, and of the clay from the banks of the Passes, bear precisely the biological characteristics to be expected under the conditions outlined. There is an intermixture of fresh-water and brackish marine organisms; while the water forming the mud is manifestly sea-water in a condition of considerable dilution, and changed by maceration with the organic débris brought down by the river. As a result of such reductive maceration, the sulphates in sea-water have been largely eliminated in the form of minute crystals of iron pyrites, and the lime as carbonate; while the ratios of the chlorids have suffered little change. The details of this investigation are set forth in my paper in the *Journal of Science,* already referred to.

Eads's Proposition to Open the South Pass

In the early 70's of the past century, even the widest of all, the Southwest Pass, had become so obstructed by mudlumps that deep-sea navigation was very difficult to maintain, despite the most active dredging on the part of the government, and the construction of tugs of enormous power, designed to pull deep-drawing vessels through the upheaved mud. Captain James Eads, the builder of the St. Louis bridge, then conceived the idea that, as the South Pass was unobstructed by mudlumps, it might be made the main and permanently navigable channel if sills of willow mattresses were placed across the entrance of the other distributaries (the Southwest Pass and Pass à l'Outre), and if jetties were constructed at its mouth to maintain a current so strong as to carry away the obstacles caused by river deposits of all kinds. Accordingly, a bill was introduced into Congress for the construction of these improvements. When this came to my

knowledge, I wrote to Captain Eads calling his attention to my investigations of the Passes and of the origin of mudlumps, and suggesting that, *so sure as the main current of the river was turned into the South Pass, mudlumps would necessarily arise;* not at once, but within a period of probably twenty to thirty years. Captain Eads replied that, while he appreciated the force of my objection, even a surcease of twenty to thirty years would be of great service to American commerce, and that it would be unfortunate to bring the matter to public notice at that time. To this suggestion I agreed; and so soon as the bill passed Congress, the work was begun with his wonted energy by the distinguished engineer. He, unfortunately, died before its completion, but it was carried out according to his plans by his successors.

A Mudlump Appears in South Pass, Confirming Author's Theory

For about twenty-five years after the completion of the jetties there was little difficulty in keeping up the required channel depth of 26 feet, 200 feet wide in the South Pass and over the bar beyond the jetties. Within the last six or seven years, however, obstructions began to appear in the channel, which the dredges found great difficulty in removing and which, when removed, seemed to be promptly renewed at the original point. Within the last year it was definitely stated in the newspapers that the obstruction was a "mud bubble upheaved by the gas from the bottom of the river; the mud being so stiff that the dredges could not handle it, and a navigable channel had to be carried around it." I, thereupon, communicated with the engineers in charge of the South Pass navigation and promptly received, from Assistant Engineer C. Donovan, a blueprint of a map showing the soundings in the jetties, and beyond and across the bar; which, by this time, has become a pretty definite ridge, as in the case of the other Passes. This map shows that the current impinges directly against a mudlump mass which has arisen across its course, but has not yet reached the water surface; and a scrutiny of the soundings shows that a maximum depth exists, even now, right at the upstream slope of the newly risen lump. The highest portions of the mudlump are still about twenty feet below the water's surface; whether naturally, or kept so by dredging, I have not learned. No eruption of liquid mud has thus far been reported, although at such a depth it might easily have escaped observation.

Possible Forestalling of Farther Upheavals

This unfortunate verification of my prediction of the event would seem to confirm pretty definitely my theory of the origin of mudlumps in general. As this confirmation is of considerable interest for the

future of deep-sea navigation to New Orleans, I think it desirable to call attention to it at the present time, in order that, if possible, measures may be taken to prevent a still farther obstruction from mudlump upheaval, *by persistent cutting-away of the present lump as it rises;* so as to relieve the pressure at the point already upheaved, and thus, perhaps, prevent the rising of additional obstructions by giving vent to the mud column at the initial point. How far this is practicable I will not venture to discuss. It is an engineering problem of no mean difficulty, considering that, in past experience, the utmost efforts of specially constructed dredges have failed to maintain a proper depth for more than a few hours or days, where mudlump upheavals had occurred in the Southwest Pass. In the South Pass there has thus far been only a single upheaval to deal with, whereas in the Southwest Pass a succession of these upheavals rendered the maintenance of the main channel extremely difficult. When we consider that in many cases the shock of the grounding of a vessel on a mudlump was sufficient to cause a quick upward movement (in one instance lifting the bow of the vessel above the water over-night), showing a state of very unstable equilibrium, it is not at all inconceivable that in a comparatively narrow channel, as is the South Pass at the present time, diligent and effective dredging might serve to cause the upheaving force to continue to spend itself on the one point where it has now acted, and so to prevent, or at least retard, the formation of new upheavals.

It is to be noted that at the present time the dredges maintain, in the seaward channel, a depth of as much as thirty-seven feet. Whether this depth, apparently excessive for the present requirements of navigation, will prove an incitement to new upheavals of the bottom is, perhaps, a question worth considering. In any case, the mudlump now lying across the mouth of the main channel of the Mississippi has doubtless come to stay, and no amount of dredging will suffice to do away with it.

THE IMPERIAL UNIVERSITIES OF JAPAN

By H. FOSTER BAIN
SAN FRANCISCO

THE public school system in Japan, as in the United States, is capped by the university. In keeping, however, with the highly centralized government of the former country, the university is controlled and supported by the imperial government, whereas in America the support of higher education has been left so far to the individual states. The imperial government now maintains two fully organized universities; one at Tokyo, and a second at Kyoto; and is organizing two more; one in the south at Fukuoka, Kyushu, and the other in the north at Sapporo, Hokkaido. At Fukuoka, medical and engineering schools have been established and others are to be added. At Sapporo only an agricultural station and an agricultural college, which go back to early American influences, are as yet in being, though the plan contemplates ultimately a complete university. In addition to these imperial schools there are important institutions of university rank endowed and supported by private initiative, and in this as in other particulars the situation shows similarities to that in the United States. Among these non-governmental schools Waseda and Keio are the largest and best known. What is said here relates exclusively to the Imperial Universities of Tokyo and Kyoto, limitations of time having prevented my visiting the others.

With the beginning of the new era in 1868, Japan faced the problem of organizing a new system of education, as well as of government, war and industry. Previously there had been no general system of public instruction, and in this, as in many other particulars, the work was essentially one of construction rather than re-construction. It would be a grave mistake, however, to consider the Japanese of the pre-Meiji eras as uneducated. While not familiar with Western learning, they were far from unlearned, and in the sense of having had their mental powers developed many of the gentlemen of old Japan were highly educated. This was especially true of the younger sons of the daimyos who, forbidden by the social system to marry or hope for headship in their own houses, were driven to the exercise of arms and rigorous study of the Chinese classics, each hoping to attract attention and be adopted as heir in another house. Failing in this, many opened private schools. In these, and other institutions whose origin is too diverse to permit review here, a severe drill in the Chinese language and literature and in Oriental philosophy, gave to the pupils a mental training not greatly dissimilar to that which our own grandfathers

received from the study of "Greek, Latin and Philosophy," in the early American colleges. When studying the rapid progress of Japan in the acquirement of western science, it is more nearly correct to think of men with B.A. and M.A. degrees derived from the study of Greek, taking to engineering, than to think of a wholly uneducated people suddenly turned loose to browse in the whole field of knowledge. Indeed, in the later days of the Shogunate, Western knowledge had already begun to penetrate the hidden country. Books brought in by the Dutch and translated into Japanese, by scholars working as did our own when first deciphering the hieroglyphics of Egypt, had a large influence if small circulation. Soon after the visit of Commodore Perry, the Shogun established in 1857 an institution for the translation of foreign books, which by easy transition became first a school of foreign languages and finally a component part of the present Tokyo Imperial University. Similarly the medical school of the university had its roots in the Seiyo Igakujo, established under the Shoguns. In the early years of the Meiji era there was a bewildering succession of organizations and reorganizations in the higher educational institutions as in other branches of the public service, but with the issuance of Imperial Ordinance No. 3 (March 1, 1886), providing for the organization of imperial universities, the institution in Tokyo took essentially its present form. In 1890 an existing agricultural college there was consolidated with the faculties of law, medicine, engineering, literature and science already organized. In 1897, with the establishment of the sister institution at Kyoto, the name was changed from Teikoku Daigaku, or Imperial University, to its present form, the prefix Tokyo being added to indicate the place of its establishment.

The imperial ordinance already mentioned is a remarkable document, warranting careful attention from educators. It evidences a close study of existing universities and their fitness to the needs of the people in both Europe and America, and a nice critical sense in the selection of those features best suited to conditions in Japan. In it, as throughout contemporary Japanese institutions, there is at the same time the germ of new things, for Japan is far from being content to adapt, and purposes to originate as well. The object of the imperial universities is stated to be "the teaching of such arts and sciences as are required for the purposes of the state, and the prosecution of original research in such arts and sciences." This article foreshadowed concisely and accurately what has become the essential characteristics of the great universities that have been established under the ordinance. Essentially the schools were to be, and are, sources of information rather than devices for mental training. They had for their field all knowledge "required for the purposes of the state" and were to be frankly utilitarian branches of the government. This, however, was not to be, and has not been, interpreted in any narrow spirit since—and in this

America may well take a lesson—research as well as instruction was to be regarded as equally the function of the university. Emphasizing the latter point, the second article provides that "Each imperial university shall consist of a university hall and colleges; the university hall being established for the purpose of original research, and the colleges for instruction, theoretical and practical." These purposes and ideals have been faithfully followed in the organization and work of each of the universities. Subsequent ordinances have provided for the financial support of the institutions and have specified the number and rank of officers and instructors; several independent government institutions, such as the Tokyo Astronomical Observatory, the Marine Biological Station, and the Botanic Garden have been added to the university; regulations as to degrees have been made, and additional facilities have been provided; but the fundamental character of the universities remains as fixed in the ordinance of 1886.

In Tokyo Imperial University there are now six colleges: those of law, medicine, engineering, science, literature and agriculture, and University Hall; the latter the research institution. At Kyoto the school, being younger, is less completely developed, the colleges being those of law, medicine, literature, and science and engineering. Here, as at Tokyo, a university hall also provides for research or graduate studies, as that term was used twenty years ago in America before post-graduate work became so formalized. The term college, as used in Japan, does not correspond exactly to usage either in England or America. The college is more nearly a "faculty," as that word is applied in the larger American schools. Each college is presided over by a director and each controls, through a faculty meeting, the curricula, examinations and qualifications of candidates for degrees. The faculty must also hold itself in readiness to consider educational or technical questions submitted by the minister of education and hence becomes an official adviser of the government on matters within its field. The directors of the various colleges, together with one professor from each, constitute the university council, presided over by the president. This council may consider questions relating to the institution or abolition of a course of study in any college, questions relating to chairs in the universities, regulations for the internal government of the institution, granting of degrees, and may suggest modifications of imperial ordinances, and of regulations by the minister of education relating to the university. The council also must, on request, advise the president or the minister of education. The president, who is appointed directly by the Emperor and ranks with a cabinet officer, has general control of the affairs of the university and, as in America, has large powers. Baron Kikuchi, the president of Kyoto University, and formerly holding the same position at Tokyo, has been minister of education and has rendered distinguished service to the state in many ways. Baron Hamao, presi-

dent of Tokyo Imperial University, was one of the pioneers of modern education in Japan and a man of great ability and influence. Such men would wield power under any system, and in Japan full advantage is taken of their abilities. The power of the president, however, is sharply limited in certain particulars where in America it is possibly too often unchecked. For example, professors are appointed by the minister of education, but "in each case that professor shall be appointed who shall have been chosen at an election held by the professors of his particular college." Professors, while not well paid in Japan, occupy a position of much more importance and dignity than in America. They are elected for three years, but may be, and are, reelected indefinitely. They receive only from $600 to $2,000 per year, but this is relatively much more than the equivalent sum in America, and they have a pension system, are paid part salary when relieved from duty for any reason, are given periods of leave of absence, are sent abroad for study in rotation, are intrusted with important government investigations at home and missions abroad, and are treated with every courtesy and respect. It is one of the curious contradictions met constantly in Japan, that in an empire a man of title gets less recognition and a university professor more than in the United States. It is true that in Japan, as in America, the professor must console himself with the honor for the inadequacies of his salary. Both that and traveling allowances are small when measured against the cost of living. Engineering professors, at least—I can not speak as to others—derive supplementary income from consulting work, though there is a strong public opinion which prevents this from degenerating into a mere scramble for dollars.

Professors, while poorly paid in Japan, are relatively numerous. At Tokyo the instructional staff consists of 6 directors, 156 professors, 93 assistant professors, and 110 lecturers; a total of 356. In addition there is an elaborate staff of university officers. At Kyoto, aside from these general officials there are 4 directors, 85 professors, 53 assistant professors, and 41 lecturers; 183 in all. Certain peculiarities of Japanese university organization will be illustrated by listing the professors in two of the colleges of the University at Tokyo. For convenience the College of Law and the College of Engineering may be chosen. In the former they are: Constitution, 1; public law, 1; civil code, 4; commercial code, 2; maritime law, 1; code of civil procedure and law of bankruptcy, 2; criminal code, 1; code of criminal procedure, 1; political economy, 5; finance, 1; statistics, 1; politics, 1; history of politics, 1; diplomatic history, 1; colonization, 1; law of administration, 2; public international law, 2; private international law, 1; history of legal institutions, 1; comparative history of legal institutions, 1; Roman law, 1; English law, 1; jurisprudence, 1. In the College of Engineering the list of professors includes: Civil engineering, 4;

mechanical engineering, 3; naval architecture, 3; marine engineering, 2; technology forms, 2; electrical engineering, 3; architecture, 3; applied chemistry, 4; technology of explosives, 1; mining, 2; metallurgy, 3; applied mechanics, 1; dynamics, 1; a total of 32. In addition, students in each college take courses in other colleges, so that the effective faculty is largely increased. Geology, for example, is taught to students in mining and engineering, by the professors in the College of Science.

In examining these lists the reader will probably be struck first with the breadth of the instruction given. For example, in no American law school of which I know is it possible to take courses in three systems of foreign law, and in America political economy and the related group of subjects would be taught by a separate faculty instead of as part of the law course. In Japan as in America, a law course is the common preparation for many branches of the public service, but in the former country only is that fact recognized by placing under charge of the faculty of law the whole of the instruction in politics and public affairs. The Japanese are an intensely practical people, and this is one instance of their regarding university education from the utilitarian standpoint—using that word, I repeat, in a broad sense. The same disposition is shown in the College of Engineering. Provision of instruction in naval architecture, technology of arms, and technology of explosives, is not common in American universities. It is the more striking since Japan maintains a separate school corresponding to our own West Point for training army officers, and others for preparing officers for the navy, the railway service, and even for educating officers for the merchant marine. University instruction in these branches is of a higher type than in these special schools, and is more closely related, through University Hall, with research. Another peculiarity is the provision of several professors in the same subject. In Japan there is more democracy and less organization within each department than in the United States. There are coordinate professors, each perhaps with his specialty, rather than a rigorous system of head professors, professors, assistant professors, assistants and so down to the *n*th order. Still another instructive feature of the system may be seen by examining the courses in some one department. For that purpose those given in mining and metallurgy at Kyoto may serve. It will be noted that the courses provide for what in the United States would be considered undue specialization and make almost no provision for fundamental training. It is true that Japanese students are supposed to have this before taking up their university work and have in fact much better opportunity for acquiring it than have American students. One may none the less retain a doubt whether in this case practise and theory run hand in hand.

MINING AND METALLURGICAL COURSES AT KYOTO

	Hours Per Week	Time
Mineralogy (Lect.)	3	4 months
Mineralogy (Exerc.)	2	1 year
Geology and lithology (Lect.)	2	1 year
Geology and lithology (Exerc.)	1	
Ore deposits (Lect.)	2	1 year
Surveying (Lect.)	2	4 months
Surveying (Exerc.)	3	
Mine surveying (Lect.)	2	4 months
Strength of constructions (Lect.)	1	1 year
Strength of constructions (Drawing)	2	
Factory architecture (Lect.)	2	6 months
Outlines of mechanical engineering (Lect.)	3	1 year
Outlines of electrical engineering (Lect.)	2	1 year
Mining, parts I. and II. (Lect.)	4	1 year
Mining, part III. (Lect.)	3	1 year
Mineral dressing (Lect.)	2	1 year
Briquetting (Lect.)	2	2 months
General metallurgy (Lect.)	2	1 year
Special metallurgy, parts I. and II. (Lect.)	5	1 year
Electro-metallurgy (Lect.)	2	6 months
Iron metallurgy (Lect.)	3	4 months
Iron metallurgy (Lect.)	2	6 months
Mechanical and metallurgical technology (Lect.)	3	6 months
Metallography (Lect.)	2	2 months
Assaying (Lect.)	1	1 year
Assaying (Exerc.)	3	
Blowpipe analysis (Lect.)	1	6 months
Blowpipe analysis (Lect.)	3	
Mining laws (Lect.)	2	6 months
Drawing, part I.	6	1 year
Drawing, part II.	6	1 year
Chemical analysis, part I.	10	8 months
Chemical analysis, part I.	15	2 months
Chemical analysis, part II.	10	4 months
Chemical analysis, part II.	9	6 months
Metallurgical experiments	6	2 months
Iron metallurgical experiments	4	2 months
Electro-metallurgical experiments	3	2 months
Experiments for mineral dressing		2 months
Practise in mine surveying		2 months
Practise in mine surveying works		4 months

The special courses noted are given by a faculty consisting of 4 professors, 4 assistant professors, and 1 lecturer; assisted by 2 professors from the College of Law. A few are given in the civil or electrical engineering departments, being required of or open to election by students in mining. At Kyoto the faculty of the Institute of Mining and Metallurgy consists of Professors Jisaburo Yokobori, Daikichi Saito, Viscount Tadashiro Inouye, Toshio Watanabe, all graduates of the

Tokyo Imperial University with doctorates obtained in engineering. In addition Dr. Yokobori studied two years at Freiberg; Dr. Saito, one year each at Freiberg, Aachen and Columbia; Viscount Inouye, three years at Freiberg, Berlin and other German schools, followed by two years in practise in the United States; and Dr. Watanabe, whose specialty is electro-metallurgy, three years at Aachen. Dr. Oda, who gives instruction in mining law, and Dr. Kambe, who lectures on industrial economy, are also graduates of the university at Tokyo, as is Mr. Tadasu Hiki, the instructor in geology, and Mr. Kenroku Ide, who has been sent abroad to study metallurgy. Mr. Tetsujiro Imanaga, and Mr. Shoji Takahashi, assistant professors, instructing respectively in mine surveying and metallurgy, are graduates of Kyoto Imperial University in engineering, who have not yet proceeded to the doctorate. Dr. Yamada Kunihiko, who instructs regarding ore-deposits, though listed as lecturer in mining, is a graduate of Tokyo with two years later experience at Freiberg. The director of the College of Science and Engineering, to which the Institute of Mining and Metallurgy belongs, is Dr. Mitsuru Kuhara, who obtained his degree at Johns Hopkins for work in organic chemistry.

Formerly, Tokyo University was largely manned by foreign professors. At present there are but 14 foreigners in the whole faculty. At Kyoto the entire faculty is Japanese except 1 French, 1 German, 2 American, 1 Chinese and 1 English lecturer. There has been some disposition to criticize the promptness with which the Japanese dispensed with the foreigners, but there can at least be no question that they have been replaced by well-trained men, and in view of the imperative necessity for economy, the move was not unnatural. As it is, nearly five per cent. of the faculty at Tokyo consists of foreigners (not counting emeritus professors) and the great majority of the instructors both at Tokyo and Kyoto have studied abroad, following courses at home roughly equivalent to that which leads to the Ph.D. degree in a first-class American university. At the time when in the United States our universities were copying most directly and actively after those of Germany, there were few professors imported from that country. We sent rather our own men to Germany to be instructed, and when they returned the movement of students abroad largely ceased. Japan has followed our example, except that she still continues to send her men abroad for final instruction if they are to be entrusted with the higher posts in the university.

A university without students is but a simulacrum, and doubtless the reader has begun to wonder about Japanese students. It is first to be noted that they are all men—for in Japan coeducation does not obtain above the elementary schools. Japanese children begin their schooling at six and for the next six years education is compulsory. It is confined to the elements of language, mathematics, nature study,

morals, geography and history and is given in Japanese. At present 96 per cent. of the children of school age are in school, and the records for attendance and proficiency are enviable. Beyond the age of twelve the boys and girls separate, but, contrary to American experience, it is the girl rather than the boy who drops out or is kept at home. The demand for instruction has from the first far outrun the financial ability of the Japanese government to provide and from the elementary school up there are more applicants than can be admitted. In general selection is made on the basis of efficiency, and competitive examinations are the usual means. The boy who, therefore, at the age of 22 or 23 finally reaches the university after passing through middle and higher schools, is the one left by a long process of elimination. It would be interesting to follow the boy through this course, but the limits of this article forbid. Those interested will find the elementary, middle and higher schools, excellently described by Baron Kikuchi, in his most instructive and readable book "Japanese Education."[1] It is sufficient to state that the student comes to the university with long training in English and one or more other languages and with about the mental training and culture that American students have when they enter the junior year of a first-class university. He is ready to specialize, has in fact prepared to specialize, and has received his training in how to study. The university course is therefore concerned more with subject matter than with method. The course is three years long and at its completion the student is entitled to assume the title of *gakushi* in law, medicine, science, engineering, or whatever line he may have followed. This, it may be noted, is not a degree conferred by the university, though roughly equivalent to our own bachelor's degree. Upon attaining to this rank the student is ready to study for the doctorate, for which five years work in University Hall is required. During the last two of these years he may, under certain restrictions, engage in practise away from the university, and before becoming *gakushi* he must, in engineering at least, spend six to eighteen months in practical work. In the latter case he is sent to a mine, smelter, or other works, and required to follow a prearranged course, reporting to the university on each piece of work as completed and receiving meanwhile help from the university, much like that given to students in correspondence courses in the United States. While in this preliminary practise he is not allowed, except by special agreement, to receive pay; the object not being to put the student into regular work on a money-making basis, but to permit him to learn practise in a commercial plant. The university reserves for its own field the teaching of principles.

Degrees are not given by the university, but by the Minister of Education upon proper recommendation. This may come either from the university or by a two thirds vote of the assembly of *Hakushi*, those

[1] John Murray, London, 1909.

graduating with the doctor's degree, of each school. The degree may be given either for completion of the regular course or for a satisfactory piece of research conducted under the auspices of University Hall. To the latter admission is either by graduation from the university with *gakushi* rank or by examination. Thus the way is open to the highest degree for the non-college trained man who is capable of doing research work and satisfies the faculty, or the graduates, as to his ability. This provision for the exceptional man is, I believe, especially commendable and stands in contrast with the growing tendency of universities in the United States to standardize everything. Degrees in Japan open the way to appointments on the bench, in the civil service, and to responsible positions in mercantile life. They are, therefore, much in demand, and there are always many more applications for admission to the universities than can possibly be accepted. At Kyoto there are now 984 students, of whom 70 are in University Hall, or, as we should say, are graduate students. At Tokyo there are over 5,000 students and there are now nearly 10,000 alumni. Of 5,737 admitted in the years 1905 to 1909, inclusive, 1,076 were graduates of the colleges, 4,709 came from the higher schools, and 1,029 were admitted by examination. Of those who enter the university a large number remain to graduate. At Kyoto the proportion is 70 per cent.; a sure test of the quality both of students and professors, though passing standards in examinations are low, 60 being a passing mark. If, however, one may judge by a very brief experience in meeting university men in Japan, few who are unfit survive. Degrees in Japan have one further peculiarity. They are revocable for anything which involves moral culpability. The *Hakushi* have the power of revoking as well as recommending degrees, though a three fourths vote is necessary for that purpose.

The University at Tokyo supports no dormitory, and at Kyoto most of the students lodge outside the grounds. They, as in the lower schools, wear uniforms and pay moderate tuition fees. Professor Basil Hall Chamberlain, speaking from his long experience says: "As for the typical Japanese student, he belongs to that class of youth who are the schoolmaster's delight—quiet, intelligent, deferential, studious almost to excess. His only marked fault is a tendency common to all subordinates in Japan—a tendency to wish to steer the ship himself." To the stray visitor Japanese students seem much like those in America. Their actual greater age is not apparent, since in Japan nobody looks as old as he is. They are generally sturdy, well set-up looking, young men. Formerly they devoted too little attention, it is said, to physical culture, but the introduction of gymnastics, changes in diet, and the introduction of sports has worked wonders. A professor in the University of Tokyo struck an answering chord when he remarked to a group of American visitors, "Yes, the campus is very beautiful—but it is not

large enough for baseball!" The latter bids fair to become the national game of Japan as it is of the United States, young Nippon taking to it as readily as does young America. In adopting the game the Japanese have also adopted the American nomenclature so that cries of "Ball two, Strike one" and "Out at first" are heard on campus and sand-lot on both sides of the Pacific. Military drill, compulsory through middle and higher schools is not, I believe, required of university students, though they show in their bearing the effects of their previous training. Those who, while in the university, become subject for military duty are excused until they complete their studies. They are also required to serve but one year and become eligible for positions as officers.

In equipment the imperial universities are excellently provided, but in lands and buildings, judged by lavish American standards, they are not so well fixed. At Tokyo the university stands within the grounds of Kaga Yashiki, the former residence of the Daimyo of Kaga, who gave the property to the government for the founding of the school. The club house is one of the old residence buildings of the Daimyo and is surrounded by a bit of landscape gardening that no art or money could reproduce without the element of time that entered into its making. Adjacent to the university is the home of the present Marquis, a part of the original holdings having been retained by the family. The buildings of the university are unpretentious, but well-planned and well-built brick structures. There is a central power station, water and sanitation have been well cared for, and for working plant the university is well provided. The same is true at Kyoto, though at both places money has been spent on men, books and apparatus rather than on buildings. The library at Kyoto consists of 255,000 volumes and that at Tokyo of about 240,000 Japanese and Chinese books, and 189,300 European and American. As Tokyo University is charged with the duty of compiling the historical records of Japan, the collection of native material is certain to increase rapidly in amount and value.

Both Kyoto and Tokyo universities support learned publications in literature, science and arts. The publications of the Medical School at Tokyo are in German, those of the Observatory in French, and the others in English, except the republication of documents relating to Japanese history, a monumental work in Japanese. The list of titles at Kyoto and at Tokyo reads not unlike similar lists from Johns Hopkins, Columbia or Chicago. As for doctor's theses, they read alike around the world, but one wonders what Shinjo Sogo, who obtained the coveted Hogakushi by investigating the subject, found to be the "Fundamental Ideas of Political Economy," and also what Naoji Oshina, Bungakushi, resolved on as the "Theory of the Moral Ideal." The study of the "Development of Pure Philosophy in India," by Taiken Kimura, should also be of interest. With the abundant materials available and the insight given by favorable historical background those who devote them-

selves to the study of eastern philosophy ought to develop results of wide value.

For the historical investigations and other special duties intrusted to the universities, such as agriculture experimentation, forestry work, support of a marine laboratory, and similar duties, funds have been provided which, while inadequate, must be conceded to be large in view of the ratio of demand to supply in the national exchequer. For general support of the universities an annual appropriation of 1,358,838 yen ($679,419) is made to Tokyo and 840,000 yen ($420,000) to Kyoto, These funds are supplemented by special appropriations, fees, donations, and income from endowment. The total sum available at Kyoto for 1911 was $728,902. Small as this amount is in proportion to the work that can be done, no one can visit the Japanese universities without being deeply impressed with the strong hold they have on the interest of the nation. A reading of the list of benefactions and endowments at either institution makes clear that this affection is bounded by neither class nor section. Scholarships and special aid funds have been established by banks, by mining, shipbuilding, and mercantile companies, and memorial scholarships of all ranks of importance have been provided. The amounts are not large, $100 to $500 being most frequently mentioned, though both larger and smaller sums have been given. With the inevitable fall in interest rate the value of the individual gifts is bound to decrease, despite careful regulations for repayment of money advanced from them. The spirit, however, that they reflect, and which at the same time they foster, will become increasingly valuable. It is this that has made Tokyo a great educational center which will more and more attract special students from all over the world. It is the inevitable result of the whole-hearted cooperation of the Emperor, the government, and the people, both rich and poor, who are earnestly working to give to beloved Nippon the best there is in education as in other things.

EFFICIENCY WAGE STANDARDS

By Professor SCOTT NEARING
UNIVERSITY OF PENNSYLVANIA

EFFICIENCY, when applied to personal capacity, signifies a maximum of return with a minimum of outlay; hence one man is more efficient than another if, with a given expenditure of energy, time, raw material or capital, he can secure a larger, though equally good, product. The term efficiency is thus purely relative, since there is no known limit to human possibilities.

Each progressive employer aims to promote the efficiency of his working force, for unless he secures a maximum return in product for a minimum outlay of administrative ability, he himself is inefficient. That manager who, other things being equal, produces the highest net return for his outlay is looked upon as the most efficient manager. Yet in producing this outlay no one factor plays a more important part than the efficiency of the labor force which the manufacturer has at his command. How then can he increase this labor efficiency? How insure a maximum productive power among his workers?

Several attempts have recently been made to answer this question practically and definitely by inquiring, "How much money is necessary to maintain an efficiency standard of living?"—that is, how much money is required to supply food, clothing, housing, education, recreation and the other necessaries of life in sufficient quantities to enable the recipient and those dependent upon him to maintain normal health, strength and intellectual acumen. A successful answer to this question will, in a measure, enable the employer to gauge the efficiency possibilities of his labor force.

Several very careful studies have recently been made, which are remarkably uniform in their conclusions as to the amount necessary to maintain efficiency in the various cities under consideration. Of these studies, by far the most exhaustive is that made in New York City in 1907 and 1908.[1]

An analysis of the family budgets of four hundred workingmen, together with an exhaustive study of food values, housing, clothing and the like, led to the conclusion that: "An income of $900 probably permits the maintenance of a normal standard, at least so far as the physical man is concerned. . . . Whether an income between $800 and $900 can be made to suffice is a question to which our data do not warrant a

[1] "The Standard of Living among Workingmen's Families in New York City," Robert C. Chapin, New York: Charities Publication Com., 1909.

dogmatic answer."[2] The family to which these conclusions referred is a "normal" family, consisting of a man, wife and three children under fourteen years of age.

In the same report appears an analysis of one hundred workingmen's families in Buffalo, with the conclusion that before they were applied to Buffalo, the New York figures should be reduced by $150,[3] and this estimate is probably confirmed by a later Buffalo study.[4]

In Homestead, a suburb of Pittsburgh, a recently completed study covered ninety-nine families, from whose budgets the investigation concludes: "It is not until we cross the $20 (a week) mark that we feel that the family is well provided for and need, if provident, have no fears for the future."

A report of the Maryland Labor Bureau contains the following statement relative to Baltimore: "A family of six living in any large American city on less than $1,000 will wear neither diamonds nor velvet, nor will their children get the benefits of high schools nor technical colleges; indeed, they will not have more than the necessities of life."

The available authorities are, therefore, in practical agreement that an efficiency standard of living can be maintained in the cities of the Middle States on from $750 to $900, varying with the family, the nationality and the city. Accepting these conclusions as a basis for further argument, we must next inquire how the wages actually paid compare with this efficiency standard, since the relation of workingmen to efficiency standards is, in the last analysis, measured by the wages which they receive.

How many men earn from $750 to $900? In other words, how many workmen receive sufficient wages to enable them to rear three children, give them enough nourishing food, warm clothes, a decent house, an education to their fourteenth year, and a legitimate amount of recreation? An answer to this problem is best sought in the able statistics of American wages.

The available statistics of classified wages, which are, in the last analysis, the only really valuable wage statistics, permit of conclusions regarding the wages paid to both males and females. The following table, containing a brief summary of the available data on the wages of adult males, furnishes the most accurate available answer to the question "What are wages?" For brevity, the table covers only five income groups, for each of which the cumulative percentages are set down. Throughout the table, these statistics are remarkably uniform. About one half of the adult males receive less than $12 per week ($600 per

[2] Supra, p. 246.

[3] Supra, Appendix V., prepared by John R. Howard, Jr., pp. 315–17.

[4] "Decencies which a Laborer's Wage Denies," Frederic Almy, *The Survey*, Vol. XXIV., p. 368 (June 4, 1910).

CUMULATIVE PERCENTAGES OF MALES RECEIVING CERTAIN CLASSIFIED WEEKLY EARNINGS. COMPILED FROM CERTAIN REPORTS 1908–1910

Classified Weekly Earnings	Massachusetts,[5] 21 Years and Over	New Jersey[6] 1909, 16 Years and Over	Kansas 1909,[7] 16 Years and Over	Wisconsin[8] 1906–7, All Males	Bethlehem Steel Works[9] 1901, All Males	Railroads[10] of the U. S. 1909, All Males
Under $ 8........	12	18	8	12	8	22
Under 12	52	57	46	59	60	51
Under 15	72	74	70	89	75	78
Under 20	92	91	91	98	92	92
$20 and over	8	9	9	2	8	8
Total employed..	350,118	204,782	50,720	128,334	9,184	1,502,823

year); while less than one tenth receive wages of more than $1,000 per year. All of the reports, therefore, present a remarkably uniform picture of the wages of adult males.

Here, then, is an effective answer to the question, "What are wages?" A study of the above table shows that half of the adult males working in the industrial sections of the United States receive less than $600 per year; three quarters are paid less than $750 annually, and less than one tenth earn $1,000 a year. These figures are not accurate, however, since they are all gross figures, including unemployment. They should be reduced by, perhaps, 20 per cent.,[11] since that reduction would make all due allowance for unemployment, varying with the year, the location and the industry. Making, therefore, a reduction of one fifth in those gross earnings, it appears that half of the adult males of the United States are earning less than $500 a year; that three quarters of them are earning less than $600 annually; that nine tenths are receiving less than $800 a year, while less than ten per cent. receive more than that figure.

Briefly summarized, the available wage data lead to these conclusions for the localities in which the data were collected, and by reference for neighboring localities. The annual earnings (unemployment of 20 per cent. deducted) of adult males employed east of the Rockies and north of the Mason and Dixon Line are distributed over the wage scale thus:

Annual Earnings	Adult Males
Under $200	——
Under $325	1/10
Under $500	1/2
Under $600	3/4
Under $800	9/10

[5] Statistics of Manufacture, 1908, Boston, 1909, p. 82.

[6] Bureau of Statistics, 1909, Camden, 1910, p. 120.

[7] Annual Report Bureau of Labor, 1909, Topeka, 1910, p. 10.

[8] Bureau of Labor Statistics, Wisconsin, 1907–08, Madison, 1909, p. 464.

[9] Report on Strike at Bethlehem Steel Works, C. P. Neill, Washington, 1910, p. 60.

[10] Annual Report Statistics of Railways, 1908–09, pp. 34 and 40.

[11] "Unemployment in the United States," Scott Nearing, Quarterly Publications American Statistical Association, September, 1909, p. 539.

Accepting as accurate the standard of living studies which set the efficiency minimum for a man, wife and three children under fourteen at $750 to $900 per year, it appears that a very large group of American wage earners are unable to support their children on an efficiency basis. If unmarried, their wage is adequate; if married, with a family of more than three children, their wage is insufficient to maintain efficiency. As the average American family is five, many of these earners are probably receiving less than efficiency wages. If this apparent discrepancy between wages and an efficiency standard of living really exists, it should have a reflex in underfed children, in undesirable living conditions, in anemic men and women—that is, in the typical products of low efficiency standards. That such products do exist, the meager data at hand indicate; but the exact character or extent of the low standard condition is most uncertain. John Spargo in a recent book[12] attempting to estimate the number of underfed children in the schools, concludes that there are between 60,000 and 78,000 such in New York City alone. A much more authoritative study is contained in a report of the Chicago School Board, which asserts:

> Five thousand children who attend the schools of Chicago are habitually hungry. . . .
>
> I further report that 10,000 other children in the city—while not such extreme cases as the aforesaid—do not have sufficient nourishing food. . . .
>
> There are several thousand more children under six who are also underfed, and who are too young to attend school.
>
> The question of food is not the only question to be considered. Many children lack shoes and clothing. Many have no beds to sleep in. They cuddle together on hard floors. The majority of the indigent children live in damp, unclean, or overcrowded homes, that lack proper ventilation and sanitation. Here, in the damp, ill-smelling basements, there is only one thing regarded as cheaper than rent—and that is the life of the child.
>
> We find that a large number of children have only bread, saturated in water, for breakfast day after day; that the noon meal is bread or bananas, and an occasional luxury of soup made from pork bones; that children often frequent South Water Street begging for dead fowl in the crates or decayed fruit; that others have been found searching for food in alley garbage boxes, and several cases were reported where hungry children at school picked up crusts of bread or fragments of lunch which other children had thrown away.[13]

Families are not only undernourished—they are badly housed as well. Here, for example, is a description of the housing facilities afforded a group of Pittsburgh steel-mill workers.[14]

> In one apartment a man, his wife, and baby and two boarders slept in one room, and five boarders occupied two beds in an adjoining room. . . . Not one

[12] "Bitter Cry of the Children," John Spargo, New York, Macmillan Co., 1906, Chapter II.

[13] Report of Minutes, Board of Education, City of Chicago, October 2, 1908, pp. 4–5.

[14] "Painters' Row," Elizabeth Crowell, *Charities*, February 6, 1909, pp. 914–915.

house in the entire settlement had any provision for supplying drinking water to its tenants. . . . They went to an old pump in the mill yard—360 steps from the farthest apartment, down seventy-five stairs. This town pump was the sole supply of drinking water within reach of ninety-one households comprising 568 persons. . . . Another row of one-family houses had a curious wooden chute arrangement on the back porches, down which waste water was poured that ran through open drains in the rear yard to the open drain between this row of houses and the next. They carried other things beside waste water—filth of every description was emptied down these chutes, for these six families and three families below on the first floor had no closet accommodations and were living like animals.

Interest may perhaps attach, in this connection, to the menu of one New York family, the children of which were considered by the examining physician to be undernourished.

Sunday.	Breakfast, bread and tea (no milk).
	Dinner, soup (from soup bone) and potatoes; bread.
	Supper, bread and tea (no milk).
Monday.	Breakfast, bread and tea (no milk).
	Dinner, fried potatoes (lard) and gravy (made from left-over soup).
	Supper, bread and tea (condensed milk in tea).
Tuesday.	Breakfast, bread and tea (condensed milk in tea).
	Dinner, boiled rice with tomatoes (canned).
	Supper, bread and tea (condensed milk in tea).
Wednesday.	Breakfast, bread and tea (condensed milk in tea).
	Dinner, boiled potatoes and stewed tomatoes (canned).
	Supper, bread and tea (condensed milk in tea).
Thursday.	Breakfast, bread and tea (no milk).
	Dinner, bread and molasses (mother out working).
	Supper, boiled cabbage.
Friday.	Breakfast, bread and tea (no milk).
	Dinner, boiled cabbage.
	Supper, bread and molasses.
Saturday.	Breakfast, bread and tea (no milk).
	Dinner, boiled potatoes.
	Supper, bread and tea (no milk).

Individual cases, like the preceding, prove nothing, and none of the data relating to the results of low standards will provide an adequate basis for scientific deduction, but it nevertheless points to conditions such as might easily be anticipated when the discrepancy between efficiency standards and wages actually paid is considered.

Is there any way in which this lowered efficiency, due to low wage standards, can be measured? Are there any directions in which it will be felt by the working force, and hence by the employer?

The standard of living facts and the wage facts are indisputable; low standard conditions are appallingly frequent in some districts. What will the end be?

The members of those families which are forced to live on inefficiency standards are subject to a decrease in (1) physical efficiency, (2) intel-

lectual keenness, (3) disease-resisting power, (4) length of life. No employer who desires to maintain the efficiency of his working force, and what employer does not desire to do so, can afford to tolerate for a moment any one of these four conditions.

He can not afford to work with a labor force which is devitalized physically. Even though modern industry does not demand of the majority of operatives great physical strength, it does demand a good physique, since neither work requiring strength, dexterity nor brain power can be carried forward efficiently and enduringly in the absence of physical stamina. "A sound mind in a sound body" is a good old saying, which holds true in a vast majority of cases.

Intellectual keenness and foresight in the wage worker is one of the essential factors in the success of the employer. Workers must be interested in their work; they must work for the firm; they must apply themselves seriously to the tasks in hand. All of these and many other commonly named requirements are impossible to attain in the face of mal-nutrition, bad housing and insanitation.

Sickness is one of the greatest foes of the manager. Hands are "off." They have headaches, colds, and like ailments in endless profusion. Irving Fisher estimates that in the United States 3,000,000 persons are at all times seriously ill; while the "well man" loses four or five days every year from minor ailments, such as colds, headaches and the like.[15] Much of the illness is preventable and would be impossible if men and women were not devitalized by low standards of living.

Employers have perhaps their greatest difficulties in replacing men who drop out of the work because of sickness or death, yet the average length of life in the United States is only half what it might well be. Men born in American cities of native white parents live on the average only 31 years.[15] The length of life in America is astoundingly short, and short because men and women have not the wherewithal to maintain efficiency—a fact which is fully established by the enormously higher death rates among the working classes. When a man or woman drops out of your factory, and you struggle for years to fill his or her place, you are often striving to cure what you might more easily prevent—early death due to low living standards.

Efficiency is an essential item in the success of any business—not the efficiency of any one man, but of the entire working group. Although efficiency is so intimately connected with success, on the one hand, it is no less closely related to standards of living, on the other. The efficiency which leads to success can, therefore, be secured only by maintaining living efficiency through the payment of efficiency wages.

[15] "Modern Social Conditions," W. B. Bailey, New York, The Century Co., 1906, p. 227.

THE INSTINCTIVE ELEMENT IN HUMAN SOCIETY

By Professor CHARLES A. ELLWOOD

UNIVERSITY OF MISSOURI

FOR two decades or more sociologists have been proclaiming that the development of their science must be through psychology and must wait accordingly upon the development of that science. Now that psychology has achieved a very considerable development and relative unanimity of opinion with regard to certain fundamentals, it is strange to find sociologists, and workers in the social sciences generally, loath to make use of some of its assured results.

Perhaps no single truth in modern psychology is better assured than that the whole mental life of man rests upon certain native reactions or innate impulses which the psychologists term instincts. Instinct has come to be recognized, then, as an all-important factor in the mental life by psychologists; but at the very time that the recognition of the importance of instinct in psychology has become universal certain sociologists are questioning the importance of instinct as a factor in human social life.[1]

This situation is serious enough to demand thoughtful consideration on the part of all interested in the social sciences. For years the social sciences, and especially sociology, have been striving for recognition as positive sciences. Such recognition it would seem can only come when sociology and the other social sciences openly rest their work upon assured results in the now recognized positive sciences. Sociology, indeed, as an intermediate science between the special social sciences and the natural sciences, can not be anything more than a study of the biological and psychological factors in human social life, with reference to certain problems, such as the problems of social organization and social evolution. It is difficult to see what place the sociologist has among the laborers in positive science, unless it is a part of his business at least to formulate the results of biology and psychology so as to throw light upon problems of social organization and social evolution.

Of course, as a matter of fact, students of the social sciences can not escape making continual use of biological and psychological facts and principles in their investigations and discussions. The trouble is that they frequently prefer to study out these facts and principles for themselves rather than make use of the consensus of opinion among the

[1] See, *e. g.*, the *American Journal of Sociology*, Vol. XV., p. 616. Cf. also the *Political Science Quarterly*, Vol. XXV., p. 514.

best authorities in biology and psychology. Very often the biology and psychology which they use is comparatively crude, and from ten to twenty-five years behind the times. It is, of course, entirely commendable on the part of the workers in the social sciences that they should not be over hasty in accepting any theory in biology and psychology. But when these theories have been tested and generally accepted, then the burden of giving adequate reasons must rest upon the sociologist who rejects such theories. Such is the case with the theory of instinct in psychology.

Aside from the misunderstandings concerning the psychological use of the conception of instinct, there are certain objections of a definite nature which students of society have made to the employment of the conception in sociology and in the other social sciences. These objections may be classified under three heads.

1. It is said that man has few or no instincts, but that he acquires practically all of his characteristics by imitative absorption from his social environment. This, however, is in direct opposition to all the results of modern scientific psychology. It is now over twenty years since Professor James upset the older view of human nature by saying that man had more instincts than any other animal. This view, after years of controversy, has finally won out in psychology and is now not seriously disputed by any one who understands what the psychologist means by instinct. Thorndike states that the list of human instincts is ever increasing because many actions which have commonly been credited to the acquisition of individual experience are coming now to be known as really the gifts of nature. He says,[2] "the more carefully mental development is investigated, the more we find human life everywhere rooted in instincts."

2. The second objection which certain students of society make to the use of the conception of instinct in sociology is that instincts, while they may exist, are in no degree determining factors in human society, but are simply rudimentary impulses whose expression is wholly determined by the social environment (chiefly economic conditions). This objection is based partly on misconceptions of instinct, partly on a faulty psychology which over-emphasizes the rôle of stimulus in initiating conduct. The full answer to this objection will be evident from what is said later.

3. The third objection which some make to the use of the concept of instinct in sociology is that instinct is but a term, a concept, and that it stands for no real phenomena; in short, that "instinct" is merely a metaphysical concept, not a reality. This objection is based upon an inadequate appreciation of the positive and biological character of modern psychology.

We shall try to show that all of these objections to the use of the

[2] "Elements of Psychology," p. 190.

psychological conception of instinct in sociology are invalid and that, if one is to study human society psychologically, one must begin with the native elements found in the individuals which compose that society, that is, with the instincts, and then show the part which they play in social organization.

A subconscious objection in the minds of many students to the use of the conception of instinct in the social sciences is doubtless the wrong use to which the conception has been put in the past. Ever since Aristotle, instinct has been a sort of a "catch-all" into which were thrown all the problems that were in any way baffling. We have had theories of social organization which traced practically everything in human society to a supposed "social instinct" in man. It has been claimed that individuals entered into social relations through this instinct or through that. The state has been explained through a specific political instinct in man; religion has been explained through a religious instinct in man; economic phenomena have been traced to the workings of a specific economic instinct, and so on. No doubt this older way of explaining man's social life through various specific instincts was unscientific and the reaction against such crude methods is fully justified. Even Aristotle's instinctive theory of society, as developed, at least, by some of his followers, is open to severe criticism because, as we shall show, man enters into social relations, not through any one or even a few, but through practically all of his instincts.

Crude recognition of the instinctive element by recent thinkers along social lines has not helped matters. The "properties of human nature," such as the aversion to labor, the love of gain and the like, which the earlier and some of the later economists have made use of, are undoubtedly very far from scientific conceptions. So also the use which certain sociologists have made of the term "unconscious," by which they seem to mean very largely the instinctive. Again the use of such a vague term as "desires," to which Ward traces all social occurrences, is open to the same objection; for some sociologists use the expression "the desires," meaning the native impulses; others mean by it the feelings.

Illustrations of vague and unscientific uses of psychological terms and conceptions in the social sciences might be multiplied indefinitely. The few that have been pointed out are, however, perhaps sufficient to emphasize that all such vague and crude uses of psychological concepts must be replaced in the social sciences by usage which is in accord with the best development in modern scientific psychology. When this is done with the conception of instinct it will be found to accord entirely with the requirements of positive science, and to be especially in harmony with the soundest biological views of life.

Misunderstandings, then, of the psychological usage of the term instinct and the resulting misconceptions of what instinct really is, are

largely at the bottom of the denial of any rôle whatsoever to the instincts in human social life. Drawing their conceptions of instinct from a crude animal psychology, many social thinkers seem to conceive of instinct as something hard and fast, as a definite, "crystallized" mode of activity, such as we find, to be sure, in the lower reaches of animal life, especially among the insects. Such thinkers conceive, accordingly, instinct as having something fatalistic and inevitable about it. But practically all psychologists are now united in repudiating such a conception of instinct. The instincts of all the higher animals, man included, are not of this hard and fast and definite type, but are modifiable through training and experience in many ways, even though they are influential in determining animal behavior. Let us see then what conception of instinct modern psychology has worked out. In man, as in all the higher animals, there is a highly developed nervous system, with multitudes of connections between its elements. These connections are pathways of nervous currents. Many of these connections are inborn and seem to be as much a part of the heredity of the individual and the race as stature, the color of eyes and hair, or any other physical characteristic. Hence the nervous system is characterized by a multitude of more or less perfectly developed preorganized reactions which are a part of the individual's heredity. These preorganized reactions have been established through the operation of selection, biologists tell us, upon variations in the hereditary elements, in the same way in which the bodily characteristics of the species have been established. In all the higher animals, and especially in man, on account of the complexity of his nervous system, these native reactions are not fixed and unalterable, but are subject in a large degree to modification or elimination according to changes in the environment. Nor are they always specific but they are often, as Thorndike says, indefinite and general.[3]

Instincts are then inborn pathways of nervous currents, which have as their functional correlate inborn motor tendencies, and as their psychical correlate inborn psycho-physical dispositions. They are evidently the psychological aspect of racial heredity, and it is as inconceivable that the organic individual should exist without them as without the equipment or general bodily structure itself. As instincts are not acquired by the individual, but are given in the germ, they are transmitted from generation to generation, varying only as other biological characteristics of the stock also vary. Inasmuch as they are characteristics of the highest and most unstable portion of the organism, the nervous system, they probably vary more widely than the grosser physical traits. They are more modifiable and alterable, owing to the fact that only about one third of the connections in the nervous system are made at birth, the other two thirds being acquired by the individual

[3] *Op. cit.*, pp. 189–190.

during his life time. These acquired connections must, of course, very greatly modify the character of the original connections, even though they are made upon the basis of the original connections. There are in man therefore no definite, hard and fast instincts such as characterize the lower types of animals, but rather a complex series of more or less generalized instinctive reactions.

It is evident that the modern psychological concept of instinct, so far from being metaphysical, is wholly biological. The concept of instinct as inborn pathways of nervous currents is the necessary correlate of the biological doctrines of selection and heredity. While the nervous system is more largely modifiable by use than any other part of man's organism, yet its essential structure is inherited and belongs to the stock or the phylum rather than to the individual. The native reactions which are inherited in the hereditary structure of the nervous system are the necessary original equipment with which the individual starts his struggle for existence. Some of these reactions are so simple in organization that they do not enter to any extent into consciousness, and these are known as reflexes. These need not concern us, since they enter directly only into the physical life of the individual organism. But the great majority of these native reactions are complex motor tendencies and have conscious accompaniments, especially feelings, emotions and "desires." Moreover, the acquired habits of the individual, psychologists tell us, are wholly built up through modification of these native reactions. When the instinctive reaction fails to function properly consciousness comes in to adapt the organism to the new situation, the adaptation being made chiefly through the selection from the varied native impulses. All of the habits of the individual therefore rest in the last analysis upon the native impulses. Now, the thesis of this paper is that if instincts are the starting point for man's mental life, they must be for his social life also; if, upon the instincts of the individual, all habits are built, so likewise upon them all social customs, institutions and organization must ultimately rest.

It should be noted that according to the modern psychological concept of instinct, instinctive reactions will vary in different individuals and races. Inasmuch as instinct represents the preformed pathways in the nervous system, made in response to demands of previous life conditions,[4] that is, created by selection, we should not expect to find exactly the same instinctive reactions in the different races of man. Their instinctive reactions, while fundamentally the same, will vary in some degree because the different racial stocks have been exposed to different selective agencies. This explains why race is a factor in social organization and evolution. Again, the two sexes have been created by somewhat different selective and developmental processes; therefore,

[4] "Response" and "demand" are of course used figuratively, without teleological significance.

their instinctive reactions to the same stimuli may often vary considerably. It is in this degree that sex enters as a modifying factor into all forms of association. Just as biological variation constantly alters the physical aspects of heredity, so it also constantly alters the inborn psycho-physical dispositions of individuals. The concept of instinct, therefore, leaves as large a place as any sociologist could desire for the influence of selection, of race, of sex and of inborn individual differences in the social life.

While there can be no question but that instinctive reactions, from the psychological point of view, are the basis of the relationships of individuals in society, nevertheless, it is very difficult to say just what proportion of human activities may be regarded as primarily instinctive. It is especially difficult to trace the instinctive element in human institutions as they exist in modern civilized society. It is certainly incorrect to explain anything important in the social life of civilized peoples simply through instinct, on account of the fact that instinctive reactions under such conditions are overlaid with a mass of habits which we term custom and tradition, and are constantly modified or inhibited by many other social factors. On the other hand, it is an equally serious error to ignore the instinctive element, even in the complex conditions of modern life. Even though we can not determine quantitatively the relations between the instinctive and acquired elements in any given social situation, it is important to note that they both exist and that the instinctive is the basis of the acquired. Some tests of the instinctive element in human society can, however, be devised by psychologists and sociologists. In general we may safely regard those activities as instinctive which characterize the species, that is, which are relatively common to all men in all stages of culture. Again, those activities which man shares with the animals below him may, for the most part, be regarded as instinctive. Finally, from the study of the child and the adolescent, the sociologist may also perceive with more or less clearness some of the instinctive elements in human conduct and character.

Another difficulty which confronts the sociologist in tracing concretely the instinctive element in any given social situation is the great complexity of human instincts themselves. It is, of course, a grave psychological error to suppose that there are a number of separate and distinct human instincts which exist side by side without running into each other and which have each a separate function to perform. Rather human instincts, corresponding to the conception of them just given as inborn pathways in the nervous system, continually run into each other and reenforce each other like a network of streams or electric currents. The consequence is that human institutions are generally expressions of a number of instincts combined in various ways, besides being, of course, often built up largely on the basis of acquired traits. It is

only in the simpler forms of association, perhaps, that we can trace most clearly the instinctive element, although all human institutions must ultimately rest upon human instincts, for the instincts are instrumental not only in furnishing the primary or original activities, but also in furnishing those "sanctions" which are the peculiar mark of those forms of association which we term institutions, since the "feelings" are more largely attached to the native reactions than to acquired habits.

It is in the simpler forms of human association, then, that we may see most conspicuously the workings of instinct. The family especially shows most clearly the influence of instinctive elements, and here it may be remarked that the family must be regarded as in many ways the most typical of all the forms of human association, illustrating in the clearest manner possible the simpler biological and psychological factors at work in human social life generally. The family as an institution evidently rests upon two great primary instincts, the sexual instinct and the parental instinct. Like all instincts, these are varyingly developed in different individuals. Sex attraction has always been recognized as the basis of human family life, and as one of the great primary forces in human society, but the influence of the parental instinct has not been so generally recognized. Careful study of human society shows, however, that it is the parental instinct which gives stability to the family, and so is the real foundation of that institution, as we understand it, in all ages and among all peoples. This is strikingly shown by the fact that, among both civilized and uncivilized peoples, childless couples separate much more readily than those that have children. It is also shown by the customs and laws of practically all peoples. The instinctive reactions of the sexes and of parents and children, then, give rise to a whole series of social coordinations which express themselves variously in the institution of the family; but this is not denying, of course, that the institution of the family, as we know it, is largely also a product of custom and tradition. To see the simple instinctive form of the family we must turn to such peoples as the Andaman Islanders, the Bushmen, the Fuegians and other primitive peoples who live a purely animal existence. In such peoples we find the simple, pairing, monogamous family group of a more or less unstable character which is practically the same as the family group which we find among the higher apes and many other animals. We are warranted, therefore, in concluding that such a form of association is not only unreflective, but also almost entirely a product of instinctive reactions.

Many of the other simpler forms of human association illustrate equally well the workings of the instinctive element. Thus the forms of play among children and the "struggle groups" of adults give very clear evidence of relatively unmodified instinctive reactions. While the social life of adults, as has already been said, is very far removed from

the instinctive plane, yet evidences of the workings of purely instinctive elements are to be found, not only in the various forms of social conflict, but also in the forms of social attraction and of cooperation. While there is no single "social instinct" which can be invoked to explain the forms of man's social life, there is a whole series of reactions connected with instinctive forms of sociability, beginning with the parental instinct. That sociability is itself an instinctive, not an acquired, trait has been amply demonstrated by the researches of practically all modern sociologists. Professor Giddings especially has shown the instinctive attraction which exists between individuals of like physical and mental traits; and that such instinctive sociability, along with the acquired traits built immediately upon it, accounts for much in our social life. More recently Mr. Trotter, a British sociologist, has shown very conclusively the obscure reactions of the same instinctive sociability in practically all phases of man's social life.[5] Illustrations of this sort might be indefinitely multiplied, but it is not necessary to do so, because all this is what any thinker would expect who takes the biological view of life. While the sociologist is not yet ready to trace in any final way the workings of various instinctive reactions in human society, there can be no doubt that such a task is scientifically feasible, and will doubtless be accomplished in the near future.

All of this, of course, in no wise denies either the influence of intellect or of objective conditions upon social evolution. As the writer has elsewhere emphasized,[6] it is the intellectual elements in human social life which after all give it its distinctive character in contrast to the social life which we find among animals. It should be remarked, however, that these intellectual elements quite as often work in line with instinctive impulses as in the way of modifying them. Again, the influence of objective conditions is, of course, to be taken for granted in considering human society from the standpoint of instinct, since no instinctive reaction can develop unless the objective environment furnishes the appropriate stimulus. It is a mistake, however, to consider that such stimuli in the objective environment of themselves give rise to the activity; for nothing is more clearly demonstrated in the psychology of the present than that the organism frequently, indeed usually, seeks the stimulus. The stimulus is not that which causes action, but is rather the opportunity for action, the organism being self-active; hence the error of those who would interpret social life and movements entirely in terms of objective conditions. The "economic determinists," for example, are under the burden of showing that all the psychological and biological factors in human nature are mediated

[5] See his article on "Herd Instinct" in the *Sociological Review* for July, 1908.

[6] See article on "The Origin of Society" in the *American Journal of Sociology*, Vol. XV., November, 1909.

and controlled in their expression by economic conditions. The mere fact that man's social life shows many traits in common with the social life of animals, among which there are, strictly speaking, no economic conditions, is in itself fairly good evidence that the native impulses are by no means wholly controlled in their expression by economic conditions, or any other single set of causes, but that they are in themselves, given the spontaneity of human nature, a determining factor in many, if not in all, social situations.

The theoretical consequences of the recognition of instinct as a subjective social factor are certainly not to be feared. On the contrary, the recognition of instinct as a factor would greatly broaden and deepen sociology and all of the other social sciences, and would bring the psychological aspect of those sciences into harmony with their biological aspects and with the biological sciences generally. The social sciences have suffered unduly from intellectualistic views of human nature and human society. As long as psychology was intellectualistic, it was unavoidable that such a significant human relation as mother and child, for example, should be explained in terms which now seem to us trivial as well as superficial. As we grasp the biological view of life and see clearly that all life is continuous, and that relations involved in human association are the outcome of forces that have been working upon life for myriads of years, and are therefore freighted with meanings far beyond the individual life, we shall avoid trivial and superficial explanations of things human. We shall see at once, for example, that such a relation as mother and child can be explained only in terms of instincts which have been created by age-long processes, and not in terms of a superficial, intellectual pity of the mother for the helplessness of her child. It should be manifest, therefore, that the concept of instinct in the social sciences will give to those sciences a vital relation to life generally. Deduction from biological and psychological facts, if carried out with proper scientific safeguards, is not to be feared in the social sciences; for it is only by accepting the results of the other positive sciences, and especially of the biological sciences, that sociology can itself hope to become a positive science.

It is only necessary to say a word in conclusion regarding the practical consequences of the recognition of the large rôle of instinct in human social life. Scientific educators have recognized now for over a decade the part which instinct plays in individual activities and development, and scientific education has made the instinctive element the basis for the scientific training of the individual. It is, perhaps, too early to judge finally the results of this movement in education, but thus far they appear to be wholly beneficent, and we are apparently approaching scientific methods in the control of individual development. The case is apparently not different in social development.

The recognition of the true rôle of instinct in human social life will serve at once as a basis for scientific social work and as a means of transcending the purely instinctive plane of social activity. It would seem, therefore, that the practical consequence of the recognition of the importance of the instinctive element in human social life would be to establish a wise conservatism with reference to the reconstruction of institutions and at the same time a progressive radicalism as regards the ultimate amelioration of social conditions. Any plan of social reorganization which is made without regard to man's instincts is probably destined to meet with as great failure as any plan of individual education which is made without regard to native impulses and capacities. On the other hand, human instincts are indefinitely modifiable, through selection in the race and through education in the individual. There is nothing in them, therefore, which can put any permanent obstacle in the way of carrying out any rational measure of social reform, although the recognition of instinct as at the basis of human social life, points to the conclusion that the only sure and probably the only safe method of social reconstruction is through education. When the instinctive element is thoroughly understood it certainly can be controlled, and in this sense transcended.

As we have seen, man's instincts were created by the selective influence of past living conditions. It is hardly probable that civilization has as yet very greatly altered the instincts of civilized man from those of the barbarian and the savage. Those persons who, like Fourier, claim that the instincts and the correlated emotions should be the supreme guide in social life would plunge society again into barbarism. Our instincts, as Professor Thorndike remarks, would be a much better guide if we were still living a wild life in the woods than they are in our complex civilized society. It is the dominance of instinctive control and of instinctive activities in existing society, rather than of rational control and rational activities, in other words, which creates many of the problems of our present civilization. As Sir Francis Galton has pointed out, many of these problems are due to the fact that man's instincts are not yet adjusted to the new and complex social conditions in which he finds himself. It is idle to think that it is practical to secure such adjustment through the elimination of socially undesirable natural tendencies by any means of artificial selection. That is too far in the future to be worthy of serious discussion. The only means which remains, therefore, of adjusting man to the requirements of a complex social life is to modify and control instinctive activities by a system of scientific education of the young, that is, by a system of social character building. The great problem of civilized society, therefore, is not to suppress man's instincts, for that can not be done, but to guide and control them by a system of scientific education, so that they will discharge themselves only in paths of social advantage.

TYPES OF MEN

By Professor S. N. PATTEN

UNIVERSITY OF PENNSYLVANIA

THE study of human types has fallen into disrepute because of the advance of exact science. Accurate measurements have displaced crude observations. In this way, the science of eugenics has been evolved with many earnest advocates who think the victories of physical science may be duplicated in social fields. Between this group and the workers in the various fields of social betterment there is a chasm and much friction. This is partly a matter of temperament, but it is largely due to the different methods of research which the two groups employ. The relation between the social worker and those he would help is personal, and his judgment of them is based on observation. His creed demands a saving of life; hence we find him engaged in the struggle to prolong life and to prevent the elimination the eugenist favors. Social elimination, he would say, is so crude a process that it sweeps off a thousand deserving persons (especially children) to the one really deserving victim of its processes.

The eugenist has an advantage in his acceptance of the doctrine of the non-inheritance of acquired characters. A direct connection is assumed between the visible trait to be favored or eliminated and the characters of the germ cell that are passed on from generation to generation. If the character make the visible trait, rigid selection based on the elimination of traits is the only way of ridding the race of undesirable traits. Improving the condition of individuals would help them, but if traits do not influence characters, such betterments would have no effect on coming generations. The social worker, however, thinks that his efforts to help individuals are of social importance, and hence sympathizes with, and suffers from the downfall of Lamarckianism. The statistical averages of the eugenist also seem to complement the work of biologists by giving an objective measure of innate characters. Biologists can not trace the determinants of the germ cell through the subsequent development of an organism. They are, however, of the opinion that the visible traits shown at maturity are the result of the action of the determinants of the germ cell. To assume that the average development shown at maturity is the index of the germ cell determinants is a natural way of completing this proof.

These facts give to the eugenists the strength they have and make their arguments seem plausible. In a recent article,[1] I have tried to point out the fallacy of their position and to put in more favorable light

[1] THE POPULAR SCIENCE MONTHLY, October, 1911.

the opinion that crude elimination does not improve social conditions. I emphasized the contrast between the unit characters of the germ cell and the visible traits observed in men at maturity. If mental and moral traits are predetermined through innate influences, the visible traits of men can not be altered without corresponding changes in the germ cell. There must also be as many individual determinants in the germ cell as there are observable traits in men at maturity. In contrast to this view, I sought to show that single characters might produce a multitude of visible effects, and that the great mass of social and mental traits could be accounted for without assuming a change in many innate characters.

Most visible traits are modifications in individuals, and not variations in germ cells. Modifications are acquired characters due to the action of the environment, social and physical, which would not appear in children if the environment were radically altered. Chastity, thrift or temperance might readily be transformed into their opposites with no other changes than the environment imposes. These traits reappear for many generations in certain families, and seem to be inborn, but we have only to make a radical change of environment to see them displaced by their opposites. Civilization and culture perpetuate themselves through the permanence of social and economic conditions. Degeneration sets in with any slump of the forces that compel a constant repetition in each generation of the acts and thoughts of their immediate ancestors.

The eugenist concept of biologic development is that of a multitude of individual characters each of which becomes visible in specific external traits. Germ-cell changes are presupposed with each change in the statistical averages obtained by the measurement of individual parts or organs. If this be true, statistical evidence based on the measurements of individual traits is proof of the presence of a corresponding character in the germ cell, and any variation in the one is evidence of a change in the other. The opposing view assumes that the visible traits usually are modifications due to the action of the environment which are not inherited, but must be reimposed by the action of external conditions on succeeding generations. Modifications of this kind do not come singly but in groups. A change of climate or of the food supply is not to be measured by a single change, but by many minor changes that alter all parts of the body. A clear upland climate will give greater vigor. This will result in greater activity through which many structures are altered. These will be followed by changes in habits and customs, creating new traits or changing the relative prominence of old ones. And finally social and political changes occur accompanied by moral and religious modifications. In these ways a complicated network of changes arise that are to be referred to ultimate changes in climate, food, health and activity. These causes create types differing

in a thousand ways, physical and social. Types are easy to recognize, but hard to measure. We use many uncertain characteristics to distinguish them, and yet must expect that any one of them will fail if it is put to a definite test.

Some changes, however, are true variations due to the evolution of germ cells. To get at these, different reasoning must be used, but the outcome is the same. As a starting point I shall take a contrast employed by the late Dr. John Ryder, of the University of Pennsylvania. He was fond of asking his students whether the hard parts of the body determined the soft parts or whether the reverse is true, thus making the soft parts determine the hard parts. The ordinary assumption is that bony structures are manifestations of the germ cell determinants. This gives the static measurements on which statistics are based, and from which the ordinary view of heredity is derived. Dr. Ryder's view was the opposite of this. He held that the bony structures were the consequence of the activity of the soft parts and were laid down later. Those parts became solid and unyielding in which the metabolism was defective. The solid ingredients of the blood were deposited there; bony structures thus came into being and seemed a part of heredity, when in reality they were a consequence and not a cause.

This view has not won general acceptance. There is, however, enough truth in it to make certain that these are dynamic characters, which must be measured not in terms of structure, but in bodily activity and its effects. An illustration of this is the contrast between anabolism and katabolism, as is also the increased plasticity manifested in the prolongation of childhood. Plastic brain cells do not result in a single mental trait, but in a change in the whole range of mental activity. The races of slow maturity differ from those rapidly maturing in many traits, and yet they may all be the result of a single variation involving the increased plasticity of brain cells. Among the psychic characters fear is an example of this kind. Cowardice, deceit, falsehood, humility and other traits are clearly the outcome of one fundamental variation. The supplanting of fear by courage would transform a whole civilization, and modify its best known characteristics. Dynamic variations are thus like environmental modifications. Groups of traits change or appear together, due to one primary cause, innate or external. Types are thus formed that differ in a thousand ways and yet are readily referred back to a few ultimate causes.

If types are formed in this way, single visible traits can not be altered unless a change is made in other traits that are due to the same cause. The changes from upland to lowland, from cold to hot climate, from damp to dry regions, or from meager to abundant food modifies many external traits at the same time. Races of men are formed by each external change which continues long enough to compel an adjustment to it. Each single visible trait does not have an independent

cause. If liquor drinking is correlated with greater physical vigor in men, an elimination of drinkers is also an elimination of vigor, and would result in race deterioration. Social causes are simpler and deeper seated than are social effects. A study of the types of men and of the relation between the various groups of visible traits must therefore precede attempts to modify races by the elimination of single traits.

Prominent differences in men arise from the contrasting effects of upland and lowland climates. An upland race, if in a dry region, has a purer and more bracing atmosphere, and hence does not need so much lung power. It must develop greater vigor and endurance, partly because of the cold and partly because of the game it chases and the cattle it herds. Its food is drier, harder and more condensed; hence a better development of the jaw and its muscles results; along with this come smaller stomachs, better digestion and fresher blood. A tall, narrow-chested man comes into being, who is in marked contrast with the short broad man of the lowland regions. These typical differences are accompanied by minor traits, not always found in all of a given race, but often enough to indicate that they have the same general causes. Long heads and round heads represent dynamic changes, even if we can not trace them back to given climatic origins. Some races and persons have a marked development of the lower face with prominent jaws and strong facial muscles. These people like hard foods, enjoy chewing their food, and, if possible, keep something in their mouth, gum or tobacco or the like, to exercise their jaws. Baseball players are noted examples of this habit; it indicates a surplus of energy and strong muscular development. It is equally plain that those with a weak lower jaw and muscles take readily to soft sweet foods, that they suck or gulp down rather than chew. This means a better muscular development of the throat. A snake, for example, sucks down its food, while a tiger chews his. In men the sweets and the meats are causes that bring out this difference between the chewers and suckers. Another like contrast is between the mouth breathers and the nose breathers. We speak of breathing as a habit, and yet different habits would not tend to be formed if muscular differences did not exist. Each activity is the outlet of energy, which tends to express itself through bodily mechanisms. The strong grows at the expense of the weak; each difference in bodily powers tends to develop a type.

These contrasted traits are valuable, not so much for the definiteness of their manifestation as for the general conclusion their study warrants. The two types of men differ somewhat in their dynamic characters, but more in the environmental modifications which climate, food and occupation have created. The upland types are tall, bony, narrow-chested with well developed lower faces. They breathe through the nose and eat hard foods. The lowland types are short, thick set, live on soft foods, and use large quantities of coarse or liquid foods.

They have a poorly developed lower face, and breathe through the mouth. The lowland races are doubtless the older type and represent the primitive characteristics of men. At some point an isolation occurred, possibly with the pushing up of the great plateau of Central Asia and the formation of dry desert uplands. An oasis or an isolated upland valley would combine, both in food and climate, the elements on which the formation of the more vigorous type depended. Later comes the renewal contact with the lowland races and the descent of the northern nomad to the fertile lowlands as a conqueror. From this union come the mixed races that occupy the medium altitudes. The upland races can not go too far down south without facing extinction, while the lowland races have been unsuccessful in facing the rigor of dry, cold uplands.

I shall call the pure uplander the long-faced type, the pure lowlander the round-faced type, and the mixture of the two, the oval-faced type. I use this contrast not because it is the only one that might be selected, but because it permits of a threefold division more readily then the others. An additional reason is that the round-faced and the long-faced women are now popular contrasts. The frontispieces of magazines give us the round-faced girl as the approved type of female beauty, while the suffragette, the old maid, the intellectual woman and the freak are pictured with long faces and protruding jaws. The difference, however, is not merely in the skull and the bony structures of the face. Even more marked is the contrast between the placid plumpness of the round face and the nervous make-up of the long face. Like differences are observed in man, and they give a ready means by which the two types can be distinguished.

In the application of current biologic theories to the human race, we must face the fact that there are two points or centers of elimination. As the race moves down or into hot countries, the upland type or the mixed type in which it is dominant is eliminated, while an upward movement, or one into cold dry regions tends to weed out the lowland type and the elements that it has given to mixed breeds. Changes in food and drink create a like and, at the present time, a more prominent tendency in these directions. Diseases also contribute their share towards this double elimination. Some, like tuberculosis, work against the upland type, while the fevers and alcohol weed out the lowlanders. The action of this double elimination can be shown by using the Mendelian law of crosses. When parents of mixed breeds unite, the children are one fourth pure of each pure type and one half of the mixed type. If none of the pure types survived, the next generation, being children of the mixed type, would again be one fourth of each of the pure types and one half of the mixed type. In each generation the pure breeds might be eliminated, and yet one fourth of the children of mixed parentage would be representatives of each pure type. Elimination

could not wipe out a type under these conditions. The unit characters on which elimination acts are plainly in the pure races, which are constantly eliminated, but constantly reappear in the descendents of the mixed types.

That this is not mere theory, but an actual condition, is shown by the way elimination is now working among the civilized races. The long-faced woman is narrow hipped and large boned. Child-bearing to her is difficult and many, therefore, do not marry. Men dislike the long-faced woman and seldom marry her unless forced by economic necessity. The result is that an elimination works against long-faced women. They become the old maids and business women, or, if married, are the source of the much-discussed race suicide. The long-faced woman disappears in these ways in each generation, to reappear in the next as the pure element in the mixed or oval-faced marriages. We can, thus, have a perpetual succession of long-faced women, even if they have no children. The round-faced woman, on the other hand, is broad-hipped and makes flesh rather than bone. Men prefer her to her long-faced sister. She gets married early and bears many children. The tendency, therefore, is to perpetuate the short, thick-set women of the type that men admire.

Among men, however, the opposite tendency prevails. The tall, nervous, long-faced man has more mental vigor and moral control. The round-faced man lacks initiative, is governed by tradition, and readily accepts the subordination, exploitation and poverty that come with defeat. He suffers more from epidemic diseases and is a ready victim of dissipation. In civilized countries his lack of earning power forces him into the slums of cities, or into the less favored occupations in the country. In these ways, he is forced into places and positions where the death rate is high. Against him, an elimination is working that cuts him off in each generation almost as fully as elimination works against the long-faced women. We thus have effective processes that weed out the round-faced man and the long-faced woman. This means that the productive unions are between the long-faced and oval-faced men on the one hand, and the oval-faced and round-faced women on the other. So long as the long-faced man is more productive, and the round-faced woman more fertile, the marriage of the two will create the mixed race found in northern countries. It is only in southern regions that the pure round-faced type prevails in both men and women.

Elimination thus leads not to extermination of existing types, but to their perpetuation. If conscious elimination is to be put in operation, it must be made to act on men and women alike. This is extremely difficult, as we admire traits in women we despise in men, and we keep them in existence by this means. We do not, for example, like a deceitful man, but men condone or admire deceit in women. The round-faced woman reproduces her lower morality in the next genera-

tion, and elements of it get into men even if, as a masculine trait, we try to suppress it. If drunkenness eliminated all the round-faced men it would not make the race immune. Alcohol does not, to any extent, eliminate women, and the round-faced type married to long-faced men would continue to breed round-faced men. We could thus have one fourth of the men of each generation die from alcohol, and still have no immunity arise to protect the race.

In contrast to this, a disease like tuberculosis mainly affects the long-faced type. Instead of letting elimination operate against them, it would seem more fitting to put them in upland regions and dry climates where they would not suffer from this disease. Better housing, food, clothing, recreation or amusements may guard against an inherited defect and give a useful life to those who, a generation ago, would have been exterminated by disease. The humanitarian and philanthropist may have been wrong in their remedies, but every discovery in science or medicine proves the soundness of their general view and puts them into a position to be of aid to the uplift of mankind. We can not, as yet, spare either the long-faced or the round-faced types. While this is true, elimination that acts on types and not on single traits must be a bungling means of social progress hurting more than it helps. When men are relocated, eat what they should and live as hygiene demands, our social traits can be reconstructed to meet the demands of a higher civilization. Disease, poverty, vice and inequality can be eliminated. Why leave the tried paths of progress for methods that might work among tigers and wolves, but which humanity has outgrown?

The gist of my argument may be put in a single question. Are we to eliminate men because of the lack of single traits, or should social elimination be the weeding out of bad types? Let me illustrate by a bit of personal experience. I recently went to an oculist, who found that I could read letters so distant that he had to use an opera glass to find that I was right. On the other hand, I had bad muscular adjustment. I combined the best eyesight with the worst muscular adjustment that in each case his practise had yielded. I would, therefore, ask, am I to be eliminated because of bad muscular adjustment, or perpetuated because of my good eyesight? Is, also, Carlyle to be eliminated because he suffers from "eye strain," or to be preserved because of his literary expression? Is John Stuart Mill to be eliminated because of tubercular tendencies, or encouraged because of his logical powers? My answer to these questions is that single defects should be remedied by action on the individual even if this remedy, say eye-glasses, must be applied to succeeding generations. It is only where we have a combination of many inherited characters in one family or group, thus forming an undesirable type, that elimination becomes a necessity. Every innate character is good; it becomes bad only in undesirable combinations or unfavorable situations.

TIME AND SPACE

By CHARLES W. SUPER

ATHENS, O.

IT requires but a moment's reflection on the part of any one in the least familiar with modern affairs to realize that the time element has come to be the most important factor in business. Railroad trains and steam vessels are run according to time schedules. Offices are opened and closed at certain hours. Employees of all classes are required to report for duty according to the clock, and their task is not completed until they have put in a fixed number of hours. New devices are constantly being placed on the market the purpose of which is to "save time," as the phrase goes. The importance that our day attaches to time is strikingly shown by the fact that for a decade Switzerland has manufactured from six to eight millions of clocks and watches annually; yet this is but a small part of the world's output. It is safe to say that on the average every adult in the United States and in the most civilized countries of Europe is the possessor of a time-piece of some sort. Time may be conceived under two aspects: it may mean a continuous current of duration flowing past a point which we call the present; or it may signify some fixed point or points in that current and the period between them. Remote time either in the past or in the future is usually designated by the term eternity. Any one who reflects soon comes to realize that he can form no concept of duration without beginning or end because it lies out of the range of experience and observation. The popular use of the word time refers exclusively to shorter and longer divisions or units within endless duration, as when we say: "I have not time to talk of this now"; "that never happened in my time"; "the train is on time." The same statement may be made of space. Although it extends in every direction to inconceivable distances, in practical affairs only that part of it is important which can be measured. What is generally called "nature" furnishes us with no accurate standard of measurement of either time or space. For the former the rotation of the earth on its axis gives us an almost uniform period which from time immemorial has been divided into twenty-four hours. No one has ever been able to explain why this number was chosen rather than some other, but it is wholly artificial. Not only this period, but its smaller units, had to be marked by some technical means. For this purpose water-clocks were invented in a remote period of antiquity. The oldest of which any information has been transmitted to us were in use in Egypt as early as 300 B.C. They consisted of a

wooden frame in which was fastened a perpendicular cylinder closed at the bottom and open at the top. In it was placed a piston and rod, and on the rod a number of cogs. These cogs were geared into the cogs of a pulley. At the end of the axle on which the pulley was fastened was a hand behind which was attached the dial-plate to a wooden frame. On the dial, each numeral from I. to XII. was marked twice, and the hand moved round the whole face once in twenty-four hours. The contrivance was set in motion by starting a flow of water from a tank into the space between the bottom of the cylinder and the piston. As the piston-rod rose it turned the pulley and the shaft, and of course with it the hand at the end. By regulating the pressure of the water in the tank, the hand could be made to move faster or slower when it was desired to lengthen or shorten the hours to conform to the relative proportion of daylight and darkness in the twenty-four. Water-clocks were formerly much in vogue in the east and were sometimes very artistically constructed. Haroun al Raschid presented one to Charlemagne that was provided with a striking mechanism and adorned with movable figures such as are now quite common. The ancient Greek designations for the time of both the day and of the night were very vague: "the full market," "candle-lighting," "the first sleep," and so on. Herodotus says the troops that were dispatched by Xerxes to get in the rear of Leonidas left the camp "about the time of the lighting of the candles." It would have been more rational to say "about dark," but he evidently used the common phraseology. Cock-crowing was accepted as an indication of time. A well-known example is given in the story of Christ's trial. It is still much relied on by the peasants in some parts of Europe. In the nature of the case the Greek designations did not indicate the same actual time at all seasons of the year, as candle-lighting would be much earlier in the winter than in the summer. Soldiers divided the night into five watches, the length of which also varied with the seasons. It is not probable that they were accurately measured. This division of time is doubtless the oldest; it is several times referred to in the old testament. Sun-dials were a good deal used by the ancients. The Greeks seem to have received them from the Babylonians. Only the astronomers regarded the hours as of equal length. So far as can be known they depended upon water-clocks. But they were of much simpler construction than the one described above, usually consisting merely of two vessels each of which had a small orifice in or near the bottom. One of these vessels was placed above the other and the water which had been poured into it allowed to trickle slowly into the one underneath. When the lower vessel was full the orifice in the upper was closed, that in the lower opened and placed uppermost, when the same process would be repeated. The speakers in the assembly were timed by these clepsydræ, as they were called; they

are several times referred to in extant orations. While they could be used at any time of the day or night, they required constant attention, and were by no means accurate. Generally the sun and the stars were depended on when they could be seen; for in the climate of Greece and the adjoining lands there are fewer cloudy days and nights than in the more northerly regions. In modern Athens about one half the days of the year are entirely cloudless, and only thirty are noted as cloudy. The Greeks used daylight almost entirely for business and rose very early. A decree of Solon is often referred to which forbids teachers to open school before daylight. For longer divisions of time the Greeks, like most of the people of antiquity, depended on the moon, but they never got the lunar months to correspond exactly with the facts. They reckoned the month at twenty-nine and a half days, or one twenty-nine, the next thirty. Their months, however, were not divided like ours and the method of counting them so as to make them correspond with the year was very complex, and the result unsatisfactory; there had to be frequent corrections to make the seasons come at the same time of the year. Yet nowhere in Greece was there ever discovered any way to obviate the inherent defect of their clumsy system. In different parts the months had different names, but were not divided like ours. There is a passage in the "Clouds" of Aristophanes in which the moon is represented as complaining of ill treatment because the Athenians had allowed their calendar to fall into confusion to such an extent that the gods were disappointed in their feasts. This made them angry with the moon—very unjustly, since the confusion in their reckoning was the people's fault. The case is very much as if we allowed our fourth of July to drift about until it ultimately came in cold weather. The lack of a fixed date for determining events gradually became generally recognized; consequently, as is generally supposed, Timæus, a Sicilian Greek, proposed the Olympiads as an era. The Olympiads, however, do not correspond with the era employed in Christian countries. Hence we have to use a rule like the following: "Multiply the complete Olympiads by four, and deduct the total from 776 for events of the autumn and winter, or from 775 for events of spring and summer." Although Timæus flourished as late as 300 B.C., earlier dates were made to correspond to his method of reckoning as well as it could be done. It is probable that much of the older chronology is erroneous. By means of observations taken on the star Sirius, both in Egypt and Babylon as early as the fourteenth prechristian century, the year was found to be about 365¼ days in length. Those old-time astronomers also reckoned by a lunar year of twelve months of 29 and 30 days alternately. This was merely a concession to custom. The moon is such a convenience for measuring periods longer than a day and shorter than a year that the incongruity between its phases and the sun's motions

was left out of account. The more intelligent people have become, the less attention they have paid to it. The defective year was brought a little nearer to the actual year by adding an intercalary month every three. The Babylonian year is supposed to have been introduced in Athens about 600 B.C. Half a century later the calendar was further improved by Cleostratus, but in all the Greek states the method of reckoning by days and months always remained a good deal wide of the mark. That the Roman year originally contained ten months is evident from the names of the last four called by them seventh, eighth, ninth and tenth (September, October, etc.), although they are in fact the ninth, tenth, and so on. July was named Quintilis, the fifth, August, Sextilis, the sixth; they were afterwards renamed in honor of Julius and Augustus Cæsar. The Roman calendar had, by the year 67 B.C. gone astray to the number of sixty-seven days, that is the civil and the solar year differed from each other to this extent. Julius Cæsar, with the aid of Sosigenes and M. Flavius, brought about the reform in the calendar which has remained substantially unchanged to the present.

The current arrangement of our calendar is a very stupid one. The seasons are not of the same length and the red-letter days fall on all the days of the week in different years. There are 186 days in the spring and summer seasons and 179 in the other two. It would be more rational to divide the year into four seasons each with 91 days and leave out of the count New Year's day and once in four years the extra day, calling it by some appropriate name, leap-year day, for example. The year should not begin where it now does, but either at one of the equinoxes or at one of the solstices. As the date, in the nature of the case, must be arbitrarily chosen it would thus at least have a scientific foundation. The calendar adopted by the French revolutionary junta was based on a scientific principle. The year began with the autumnal equinox of 1792 and consisted of twelve months of thirty days each with five complementary days, to which was added every six years an intercalary day. The months of the year with their names succeeded each other in the following order: Vendemiaire, Brumaire, Frimaire, Nivôse, Pluviôse, Ventôse, Germinal, Floréal, Prairial, Messidor, Thermidor, Fructidor. The month was divided into three decades. The days were named numerically, Primidi, Duodi, and so on. The fifth (Quintidi) and the tenth (Decadi) were designated as days of rest. The five or six complementary days were named Fête de la vertu, Fête du genie, Fête du travail, Fête de l'opinion, Fête des recompenses and Fête de la revolution. This calendar remained in force until January first, 1806, when that of Pope Gregory was restored by decree of Napoleon. Three Roman emperors after Augustus tried to substitute their own names for months instead of those in current use, but they were not permanently successful. Charlemagne also proposed to displace the heathen names

of the months by others that he considered more appropriate, but in this he also was unsuccessful. Christian Europe still clings to the names of the months as they were named by the Romans. It may be said, however, that in some parts of Germany February is known by the title given to it by Charlemagne. The change from old style to new was made by all the governments of western Europe except England and Sweden before the middle of the eighteenth century. In the former country, antipathy to the Pope and the natural conservatism of Parliament resisted a change until dates were eleven days out of the way. It was finally brought about under the Pelham ministry on the motion of Lord Chesterfield, who was, however, merely the "big-wig" put forward to give the measure prestige. He knew very little about the subject, but he knew his audience. Some time afterward he wrote to his son:

> I consulted the ablest lawyers and the most skillful astronomers and we cooked up a bill for the purpose. But then my difficulties began. I was to bring in this bill which was necessarily composed of law-jargon and astronomical calculation, to both of which I am an utter stranger. However, it was absolutely necessary to make the House of Lords think that I knew something of the matter; and also to make them believe that they knew something of it themselves, which they do not. For my part, I could just as soon have talked Celtic or Sclavonian to them, as astronomy, and they would have understood me fully as well; so I resolved to do better than to speak to the purpose, and to please them instead of informing them.

The change was, however, not so simple an affair as it might seem. A number of matters had to be regulated by law, especially rent-days, annuities and salaries. The year was henceforth to begin on the first of January instead of March 25, and September 2, 1752, was to be called the fourteenth. The populace was much disturbed by the shifting of the saint-days and immovable feasts. Lord Chesterfield's chief advisers were the mathematicians Macclesfield and Bradley. When some time subsequently a son of the former was a candidate for parliament one of the popular cries against him was: "Give us back our eleven days"; and when a number of years later Mr. Bradley died of a lingering disease, many persons attributed his sufferings to the part he had taken in changing the calendar. Verily, "Genius has its limitations, but stupidity has not." The ancient Romans, like the modern English gained the reputation of being an eminently practical people. But just as the latter cling to an awkward system of coinage, so the former adhered for centuries to a method of reckoning time that hardly passed beyond the stage of puerility. There is no evidence that they even divided the day into hours until the third century B.C. In the year 263 Valerius Messala is said to have carried away, among other trophies captured at the taking of Catania in Sicily, a sun-dial, which he set up in Rome. It was in use an entire century before even the officials be-

came aware that it was not correct for the meridian of Rome, although the latitude of Catania differs from that of the capital by more than four degrees. From that time forward sun-dials came into general use; and since many have been recovered their construction is well known. The most common form is that of a concave hemisphere cut in two. Within one of these quarters the hours were marked. A stylus or hand fastened in the top indicated the time of day, when the sun shone. Pliny says the first water-clock was set up in Rome 159 B.C. These water-clocks appear to have differed from the clepsydræ that had long been in use in the countries farther east. They consisted of an earthen vessel tapering downward to a point, in the bottom of which there was a small hole through which the water flowed in a given time. It was comparatively easy to ascertain when the sun was on the meridian; but not so easy to determine the exact period of midnight. This was moreover, an affair of small practical importance. In the larger cities, the periods or hours were announced by the sound of a trumpet; in the country few persons cared how the hours of the night passed. The custom of proclaiming the hours of the night prevailed in some countries of Europe, especially in Germany, long after clocks had come into almost universal use. It is not known when the Romans began to divide the day into twenty-four hours. At any rate there were two kinds of days in vogue: the astronomical day, the hours of which were all of the same length, and the civil or ordinary day which corresponded with the former at the equinoxes only. The popular day was a matter of latitude. In Rome the longest contains somewhat more than fifteen hours according to mathematical calculation, but owing to the Appennines which lie east of it the fact does not quite correspond with the figures. The hour in Rome was therefore at one time of the year about seventy-five minutes in length, while the hours of the night were correspondingly shorter, and *vice versa.*

Every schoolboy is taught that twelve inches make a foot, but not one in a million thinks to ask what is the basis of this measurement. It must at once occur to the occasional inquirer that the average human foot is not twelve inches long. When, however, a unit of measurement has been once fixed, the rest is easy. The metric system was the first attempt to establish an invariable standard to which recourse could always be had in cases of doubt. A table before me gives twenty-six different lengths for the foot in the German empire, twenty-five for the rest of Europe, eight for America and four for Asia. Of these the longest is that of Lombardy, which contains a little more than 435 millimeters, the shortest the foot of Siam, which is only 245.6 mm. Even in Germany the foot varies from 429.5 to 250 mm. There is of course the same divergence between the square and the cubic foot. The Eng-

lish foot contains 304 mm., which is usually held to differ slightly from that in vogue in the United States. Until there was a great deal of national and international intercourse the need of some uniform standard of weights and measures was not seriously felt; consequently the efforts of physicists in the seventeenth and eighteenth centuries did not receive much encouragement. Absolute accuracy in matters of this kind is unattainable, but in practical affairs it is not particularly difficult. What the term "accuracy" means to a maker of instruments of precision is forcibly illustrated by an anecdote told of John A. Brashear, of Pittsburgh. A prospective customer once asked him what it would cost to have a bar of glass made that was absolutely straight. Mr. Brashear would not promise absolute straightness, but was willing to come as near as he could for two hundred thousand dollars. After listening to a lecture on absolute accuracy by the renowned mechanician the customer concluded that his needs would be supplied by a ruler that would be correct to the one sixty-fourth of an inch and costing about forty dollars.

Physicists became convinced long ago that the only fixed standard of linear measure is some portion of the earth's circumference. No intelligent Greek or Roman from the time of Plato had any doubts about the shape of the earth. But after the Bible had come to be recognized as an authority in science as well as in doctrine the belief was gradually abandoned and various theories took the place of the true one until the time of Copernicus. Archimedes, about 200 B.C. used an ingenious argument to prove the sphericity of our planet. As water always seeks the lowest level the ocean must be equally deep everywhere and the bottom equally distant from a central point. As this is possible only in the case of a sphere, the earth must be spheroidal in form. The first attempt to calculate the circumference of the earth was made by the celebrated savant Eratosthenes in the third century B.C. Observing that the difference of latitude between two points in Egypt, Alexandria and Syene, was 7° 12′ and supposing them to be on the same meridian, and having ascertained as best he could that they were about five thousand stades apart, he reckoned this to be the fiftieth part of the earth's circumference, which would accordingly be 250,000 stades. More than a century later Poseidonius estimated the distance between Rhodes and Alexandria, on the testimony of seamen, to be five thousand stades, or one forty-eighth part of the circumference. Putting the value of the stade at six hundred feet—authorities vary considerably on this point—both estimates must be considered a remarkably close approximation to the truth.

In 1525 Fernel measured the distance between Paris and Amiens with a wheel. Almost a century later Snellius discovered, or rather rediscovered, trigonometry, which greatly simplified geodesy. By this

method he measured the distance between Alkmaar and Bergen-op-Zoom, using thirty-three triangles. He obtained nearly the same results with Fernel as to the circumference of the earth. Since that time similar work has been going on almost uninterruptedly. In 1669 Picard measured the meridian Amiens–Malvoisine, and from it estimated the circumference of the earth to be 20,541,500 toises or fathoms. Picard's figures were used by Newton in the studies which led to the discovery of the universal law of gravitation. At this point in the investigations the question arose whether the earth is a perfect sphere or a spheroid. In order to solve this problem two expeditions were fitted out, the one to operate in Peru, the other in Lapland. Both occupied several years, completing their labors about 1740. The results obtained settled for all time the relation of the polar to the equatorial axis. Geodetic surveys are, however, still in progress. The most extensive of the older projects was completed by Arago and Biot in 1808, based on the labors of Mechain and Delambre. The meridian measured was that between Dunkirk and Formentera, an island near the Mediterranean coast of Spain. This arc extended over twelve degrees and twenty-two minutes. The principal object of this survey was to establish a fixed unit of linear measure for the meter, which was to be the one ten-millionth part of the earth's meridian quadrant. This is the so-called *métre des Archives,* a platinum rod deposited in Paris. Although it is now known that it is not strictly correct there is no probability that it will ever be changed, as it has become the foundation of the metric system. In 1861 general Baeyer proposed the measurement of the meridian Christiania–Palermo. The work was to be carried out by the European governments conjointly. The proposal led to a general conference of savants in Berlin in 1862. A permanent commission was organized under the presidency of General Baeyer.[1] Another conference was held in Berlin in 1867, all the governments of Europe, except Turkey, having in the interval promised cooperation. Since then meetings of the commission have been held every two or three years, their object being the continuation and revision of the French measurements to Algiers, a complete triangulation of the Mediterranean Sea, the measurement of a parallel through Central Africa from Cape Town to Upper Egypt, and to take such other observations as usually fall within the scope of a geodetic survey. For many years the United States government has been engaged in measuring the ninety-eighth parallel which extends from the southern point of Texas to the Canadian border. Strange as it may seem in view of what they accomplished in several directions,

[1] The Prussian general Baeyer, who died in 1885 at the age of ninety-one, probably devoted more years to geodesy than any other man of modern times. He began his practical studies in 1816 and published his last work in 1881. He cooperated with Bessel in many of his measurements and astronomical observations.

the ancients had almost no knowledge of machinery. Water power was called into requisition to a limited extent, but the main reliance was on the muscular force of man and beast. In the East and in Egypt, the potentates tried to impress their contemporaries and posterity by the vastness of their structures; the artistic sense of the Greeks led them to make only such objects as were beautiful. But even the Romans who were intensely practical in most things never constructed labor-saving machinery. It is no explanation of the fact to say that actual or virtual slavery was the cause of this lack of enterprise. The same conditions prevailed throughout the Middle Age after slavery had been to a considerable extent abolished. Machinery can hardly be said to antedate the era of steam. Although time-pieces can not properly be called machines, their construction requires a knowledge and appreciation of the mechanical powers. It is in strict conformity to the law of progress that water-power which had been in use for purposes of propulsion for thousands of years should also be employed in the manufacture of time-pieces.

We need to be often reminded that the phrase "to save time" is one of the most frequently misapplied in our language. If we can cross an ocean or a continent in five days instead of the fifty formerly required, where have we saved any time, if we make no good use of the forty-five we are supposed to have saved? If we can converse with a person ten miles or a hundred or even a thousand miles distant without stepping out of doors, where is anything gained if we have nothing to say that is worth saying? If by means of so-called labor-saving machinery we are provided with a thousand pages to read for every one that was within easy reach of our grandfathers, how are we better off if very little of it is worth reading? We are losing rather than saving time in the operation. The truth is that nothing worth doing has ever been done in a hurry. Almost all the great discoveries and inventions that have really benefited mankind are the result of much patient thought and investigation and experiment. The same is true of every work of art, whether pictorial or plastic. After they have become public property their use is a mere matter of routine and imitation. The more time we "save" the less we seem to have. The more we rely on machinery to do our work, the more nearly we become machines ourselves. Even our educational processes have largely degenerated into mere mechanical routine. Each pupil and student is taught to do what he has seen others do. Most of our young people are advised to transform themselves into living cash-registers as early as possible, although the coins they handle are for the most part either counterfeit or of small value.

PROFESSIONAL TRAINING FOR CHILD HYGIENE

By LEWIS M. TERMAN

ASSISTANT PROFESSOR OF EDUCATION, STANFORD UNIVERSITY

NO one acquainted with the problems of professional education can read Mr. Abraham Flexner's exposé of the status of medical education in the United States and Canada without a feeling of profound gratitude. His description of conditions is so masterly and variegated as to give the impression of utter completeness. It would seem that nothing had been forgotten. On further consideration, however, this appears far from being the case. Mr. Flexner has confined himself to an exposition of the shortcomings of medical education with exclusive reference to the ideals, purposes and standards of the best present-day medical schools. The social sufficiency of these ideals and purposes he seems to take for granted. For him, as for the practising physician, the main business of medical education is to train men in the scientific diagnosis and therapy of existent disease. The yet more important duty of the medical school to train men for scientific work in the several prophylactic fields of child hygiene is not even suggested. Let us glance briefly at this neglected aspect of preventive medicine.

Civilization has necessitated a tremendous readjustment of life habits. The factors which controlled and directed the evolution of the human organism have in large part become inoperative. Our modes of sedentary life tend less and less to bring into play the physical traits which were of most teleological value in the primitive struggle for existence. Instead, excessive burdens are laid upon functions and organs never intended by nature to endure them. If only the intentions of nature were respected during the period of growth and development the problem would by no means be so serious. The youth who had been brought into possession of his full psycho-physical inheritance would be in a position to conserve this inheritance in the face of great odds. This we do not permit. The introduction of universal education has changed the whole life of the child from one of active to one of sedentary occupation. As stated by Gulick, "so extensive a readjustment of the life habits of the young of a species has never before been attempted." Nor is it reasonable to suppose that man presents any exception to the biological law that the ultimate survival of an organism is threatened whenever it is subjected to conditions of environment widely different from those which directed its evolution. We have taken the child out of its natural habitat of open air, freedom and sunshine and for half his waking hours we are subjecting him to an

unnatural regimen which disturbs all the vital functions of secretion, excretion, digestion, circulation, respiration and nutrition. Even the very anatomy of the bones themselves, both gross and fine, is markedly affected.

The fact that the school doctor has been called in to examine and advise does not signify that the gravity of the situation has been apprehended. Teachers have simply found physical defects an impediment to the pupil's school progress and desire their removal. The school doctor spends some three to six minutes in the examination of each pupil, looking only for the gross and external symptoms of defectiveness. Having strictly the point of view of the physician, his search is for disease. His training has not fitted him to scent out delicate, incipient deviations from the normal nor to see the necessity of doing so. He does not have a biological conception of the functions of child hygiene. To appreciate the importance of the school health officer we need only to enumerate some of the problems most in need of investigation by men scientifically and specifically trained for the purpose. The following are some of these questions—not one of which can be satisfactorily answered in the light of our present information.

What is the exact nature and extent of the effects of school life upon the vital processes and upon growth? What changes, for example, does the child's blood undergo during the school year in number of red and white corpuscles and in percentage of hæmoglobin? What happens to the blood during a well-spent summer vacation? How does the sedentary work of the school affect the growth of the heart and its muscular force? How common is malnutrition among school children, and what are its causes? To what extent is the school responsible for the curse of constipation? What is the relation of book work to lung capacity, and just how seriously does sub-normal lung capacity menace the future health of the child?

What physiological changes are induced by the high temperature and low humidity of ordinary school-room air? Is it true, as recent experiments suggest, that the goal for which the mechanical engineer strives in the ventilation and heating of a school building, that is, the maintenance of an absolutely even temperature and the avoidance of perceptible draft, is the worst possible condition that could be secured? Is it true that keeping the relative humidity of the schoolroom air up to 50 or 60 per cent., the temperature down to 60 degrees or below, and permitting perceptible drafts which will keep the skin practised in the exercise of vaso-motor control should be matters of far more concern than avoiding the usual slight depletion of oxygen or the excess of carbon dioxide? Is respired air poisonous? If so, by virtue of what properties?

What are the special characteristics of school dust? Which kinds are most injurious? What part does dust play in the dissemination of

school diseases? What are the exact results following the introduction of the vacuum cleaner in the school? What are the indirect effects of pure air on the processes of nutrition and growth? Can school air be made hygienic? What results from the combination of deep breathing and dust in the average indoor gymnasium? Is exercise thus taken better in the long run than none at all?

Is it true, as certain recent researches suggest, that forty or fifty per cent. of all school children contract tuberculosis at least once before the end of the school course? How does the incidence of tuberculosis among school children vary with different climatic, social and industrial conditions, and with different methods of school sanitation? Probably two million children now in our public schools will die of this disease. Would systematic researches make possible the earlier diagnosis of active cases, or even the certain detection of constitutional predisposition to the disease? Does any one know that we could not by segregation of such pupils in open air schools and by carefully regulating their diet save the lives of half or three fourths of this two million?

What produces hypertrophied tonsils and adenoids? Are they connected with the disturbances of lymphatic circulation and of nutrition due to the sedentary school life? By what mechanism do they produce such deplorable stunting effects on body and mind? To what extent, as statistically determined, do they predispose to tuberculosis and other throat and lung diseases? Are they a necessary incident in the growth of 10 or 15 per cent. of our children? Is it sufficient merely to wait for their appearance and then call in the school doctor to remove them?

What is the relation of the school to the neuroses? Is the school a factor in the undoubted increase of insanity? Does school overpressure, as some psycho-pathologists believe, lay the last straw in the case of those predisposed to neurasthenia, hysteria, or dementia præcox? Of the 18,000,000 children now in the public schools, the lives of probably a half million will be rendered miserable failures because of one or another of the neuroses. May we hope that scientific research in the etiology of nervous diseases will make it possible to segregate the "emotive" cases and apply a psycho-prophylaxis which shall lead them to a normal mental life?

Over half of the pupils fail to progress through the grades at the expected speed. What are the causes of retardation? To what extent is it an expression of congenital mental deficiency? How many mentally deficient children are in our schools? What are the respective values of heredity and environment in the etiology of feeble-mindedness? How common is the *moron*, that is, the grade of intelligence lying between the merely "dull" and the "feeble-minded"? What proportion of morons become criminals? What kind of education must they receive to insure that they shall not become social burdens or pests? By what means shall we classify them and on what bases?

What connection, if any, has moral instability to such physiological abnormalities as impacted teeth, irritating conditions of sexual organs, nasal occlusions, intestinal parasites and circulatory stagnations due to over-much sitting? What is the relation of mental and physical deficiency of children to alcoholism, syphilis, tuberculosis, or long continued dietary insufficiency during the period of growth?

What is the relation of oral hygiene to general health? What factors underlie the individual differences of children in predisposition to dental caries? How is this "disease of the people" related to nutrition, both as cause and effect? How is it related to school progress and morals? Is Osler justified in asserting that the problem of oral hygiene is of more consequence to racial welfare than is the alcohol problem?

What influence upon educational practise may we expect from the modern methods of roentgenographic determination of anatomic and physiological age differences? How large are such differences among children of the same chronological age? Does mental growth correlate with skeletal development, or with physiological age as determined by dentition and sexual maturity, or with chronological age, or with none of these? Current methods of promotion tend to a gradation by chronological age. Is it certain that this has more to commend it than a classification on the basis of height or weight? What percentage of school failures is due to subnormal physiological maturity? Should we always appeal to the roentgenograph to help decide doubtful cases of promotion? How frequently is nervous overstrain connected with a neglect of physiological age differences?

What are the physiological effects, *ultimate,* as well as immediate, of current methods in physical training? How are we to explain the surprisingly unfavorable showing of athletes in life-insurance statistics? Is it frequently justifiable to subject children to "corrective" gymnastic exercises in preference to free play? Just how, physiologically, does exercise which is enjoyed differ in its effects from exercise which is not enjoyed? Is the difference comparable to the difference found by Pawlow in the secretion of saliva and gastric juice under varying emotional conditions? What sports can safely be indulged in by children of different ages? Can any one state authoritatively what percentage of 16-year-old boys ought to attempt the five mile run? Might not research (research along these lines is now as rare as it is precious) teach us more reliable methods of diagnosticating athletic fitness and unfitness? (Professor Clark Hetherington is authority for the statement that not one physician in a thousand can make this determination.) What are the permissible limits of athletic specialization? What is the relation of muscular power to mortality and morbidity? Is current playground and gymnastic instruction sufficiently differentiated for age and sex differences? How far may physical training

for girls safely be modeled after that for boys? What time in the day should exercise in physical training be given? How should it alternate with other school studies? Can it ever safely replace the old-fashioned free "recess"? Just what does it mean, physiologically, for a muscle to be "trained"? Which of the half dozen or more theories is the correct one? How far can training be bunched? Does training produce fatigue bodies and anti-bodies, as Weichardt thinks he has demonstrated?

How many hours daily should children study? Can any one disprove Dr. Weir Mitchell's assertion (which seems to be the belief of most psycho-pathologists) that children could accomplish as much as they do now if the school day were only half as long? What is the most favorable alternation of work and rest periods in mental hygiene? What is the diurnal course of mental (also moral) efficiency? When is the assignment of home study justifiable? How do the results of home study compare in quality and quantity with school study? Is there much or little ground for the frequent charges of overpressure made against the schools? Is school overpressure responsible for any of the recent and marked increase in child suicides?[1]

Investigations into the sleep of school children show that they sleep on the average nearly 25 per cent. less than "authorities" have usually set as a safe norm. Is there a real sleep insufficiency of 25 per cent., or has the amount needed been overestimated? In the matter of sleep what are the safe limits of habit adaptation? What is the relation of sleep to school progress, nutrition, morbidity and conduct?

The human eye was evolved to satisfy the demands of *ordinary* vision—that is, to make on the average 15 or 20 movements per minute, under conditions which permit frequent shifts of accommodation and convergence. The work of the school demands of the immature eye that it execute for several hours a day an average of 150 to 200 separate movements per minute with as many rifle-aim fixations and with a uniformly intense strain of the muscles of accommodation and convergence. What is the relative importance of these factors as compared with heredity in the etiology of ocular defects? How does malnutrition affect the eye? How much truth is there in Dr. George M. Gould's assertions regarding the reflex effects of eye-strain upon general health? What is the minimum size of type that should be permitted for children of different ages? What are the optimum norms for width of stroke, spacing of letters and words, length of lines, color of paper, and intensity of light? Is the complete conservation of vision possible?

What conditions of health obtain among the one-half million school teachers in the United States? What kind of physical constitution

[1] See Albert Eulenberg, "Schülerselbstmorde," *Zt. f. Päd.-psych.*, 1907, pp. 1–81. Also Louis Proal, "L'éducation et le suicide des enfants," Paris, 1910.

does the profession attract? How many are tuberculous? What proportions suffer from insomnia, obsessions, neurasthenia, eye-strain, headaches, heart-disturbances, indigestion, constipation, or other functional derangements? What constitutes overwork of the teacher, and what are its reflective effects upon the pupils? What is the status of personal hygiene practise among teachers? How many of them are in the "patent-medicine-stage" of ignorance? What fraction of them do not appreciate the difference between an oculist and an optician? Is it vain to hope that our half million teachers may yet be made so many missionaries of public health? If so, through what methods of teaching hygiene in the schools? How do different methods of teaching physiology and hygiene differ in their effects upon life habits? What is the best approach in teaching "scientific temperance," or the still more difficult subject of sex hygiene? Should the latter be taught in the public school? At what age? What should be the content of such instruction?

The greatest problem of conservation relates not to forests or mines, but to national vitality, and to conserve the latter we must begin by conserving the child. *Let it again be emphasized that hardly a single one of the above questions is fully answerable to-day.* Not many of them will be fully resolved until they have been attacked on a broad scale by systematic and scientific methods of research. To secure proper scope for such research the schools must be thrown open to it; to insure adequate support it must be made a public undertaking. The school instead of causing sickness and deformity must be made to preserve the child from all kinds of morbidity, repair his existent deformities, combat his hereditary predispositions and the bad conditions of his social environment, in a word fortify his constitution and render him physically and mentally fit for the struggles of life. The value of research carried on for this purpose will depend most of all upon the type of man intrusted with it. The teacher can not do it; the superintendent or principal can not do it; no more can the average school physician.

Who is the school physician and what has been his training? With a few notable exceptions he probably differs little from the average practising physician, and since the merciless brochure of Mr. Flexner it is unnecessary to dwell at length on the positive unfitness of the *average* physician for any research, to say nothing of the highly specialized kinds here advocated. Suffice to say that Mr. Flexner finds only about 30 respectable medical schools in the entire country; that twenty years ago there was not one; that a large fraction of our physicians "walked into the profession from the street"; that over one half the schools require less than a high school-course for entrance; that half or more have little or no laboratory facilities for physiology, pharmacology or bacteriology; that many do not even teach the use of

the microscope; that the teaching of anatomy and pathology is often entirely didactic; that clinical facilities are usually inadequate and in many cases practically lacking altogether; that many are squalid, "reeking with commercialism," and "without a redeeming feature of any kind." Such has been the making of a large numerical majority of our physicians. Additional comment would be superfluous.

But what of those physicians whose medical training, as such, is above reproach? It would be unjust to confound them with the average practitioner who is ignorant alike of the principles of medical science and of child hygiene. Nevertheless, it must be said no less emphatically that the ideal equipment for the school health officer is vastly different from that required for the successful practise of medicine. The physician is "long" on certain qualifications of little value to the school health supervisor and as much "short" on others extremely important. When he enters the school he leaves his obstetrics and his pharmacology behind. On the other hand, he needs to know a great deal about such questions as those propounded in the first half of this article, the solution of many of which is in no way made easier by the best medical equipment. As a matter of fact and common sense, if the work of the school health officer is to remain confined to the hasty and superficial kind of examination usually given by the "medical inspector," then we had better forego the luxury of physicians and employ trained nurses instead. After a few months apprenticeship the nurse could make the usual tests of sight, hearing, etc., as well as the physicians are making them. Already in some of the large cities (San Francisco and Oakland, for example) nurses are actually doing, under supervision, practically all the routine work of examinations. As for the ordinary tests of vision, the teacher of average intelligence can make them as successfully as the *physician who is not also oculist*. A considerable number of the best oculists in the country have officially taken this stand.[2] The point is not that the work should be narrowed to what the teacher can do, but rather that it should be extended beyond the functions of the physician.

The physician, after all, is only a physician, which is as much as to say that he is not a hygienist in point of view. He has learned something of the science and art of discovering and curing disease. At best he has also learned a little of the general principles of preventive medicine, but of the many special relations of preventive medicine to the school he knows extremely little. He is ignorant of the technical aspects of education, of child psychology, of the psychology of mental deficiency, and of a host of common developmental abnormalities. If he knows anything of mental hygiene and psycho-prophylaxis it is not to the credit of his medical school, for not a half dozen in the country have yet taken any account of the late epoch-making developments in

[2] See Gulick and Ayres, "Medical Inspection of Schools," pp. 105–6.

psycho-pathology, wrought by such investigators as Freud, Jung, Prince, Sidis and Adolf Meyer. The situation may be summed up in a sentence: *The physician's training does not qualify him for the many sided task of adapting the program and environment of the school to the health and growth needs of the pupil.* The main purpose of this article is to suggest tentatively and somewhat roughly some of the more important lines of professional preparation necessary for those who are to work in any field of child hygiene in the public schools.

Educational hygiene has four chief aspects: (1) "Medical Inspection," including routine examinations for physical defects and consequent follow-up service; (2) supervision of physical training, including free play, gymnastics, and athletic sports; and (3) child psychology, including clinical work with mentally and morally atypical children, the hygiene of instruction, etc.; (4) researches in school heating, lighting, ventilation, seating, sanitation and other externals affecting the health of the child. Each of these divisions has of course its logical subdivisions but as only the very largest cities could employ a more specialized staff than this scheme calls for it is unnecessary to carry the classification further. On the other hand, the majority of school health officers will probably for some years to come have to serve more or less in all these capacities. Assuming, however, the four separate lines of specialization above designated let us examine the general and special courses of study which would be necessary for their successful pursuit.

To begin with, it would seem that the time requirement could not reasonably be placed below seven years in addition to a four year high school course. This corresponds to the usual allotment for the doctorate of philosophy and to that for the doctorate of medicine in our sixteen best medical schools. Using the seven-year basis for our calculation, the course falls naturally into three divisions. The first three years would be given to regular college work in which the elements of physics, chemistry, biology, physiology, psychology, paidology, sociology and at least one modern language would be taught. The next three years would be ample time in which to give all that is needful *for the school health officer* out of the present medical curriculum, besides leaving a fair margin for collateral work in psychology, paidology, and the technical aspects of education. The last year would be reserved for carefully supervised clinical practise in the public schools. Proof of ability to read both French and German should be required a year before the end of the course, for most of the important researches in school hygiene are in these languages.

Physicians will of course object to the time allotment for the second division. How, they will ask, can you condense a medical course into three years, to say nothing of a margin to be left for psychology and paidology? The answer is more in terms of elimination than of condensation. Pharmacology, materia medica and therapeutics can be dis-

carded in a lump, with a consequent saving of a full half year. Doing the same for the obstetrics, gynecology and most of the surgery effects a further saving of three-quarters of a year. This makes a year and a quarter off the present medical course. Further, for the purpose here in question, minor savings could be effected in several subjects, as, for example, anatomy, in which the minimum of 400 hours required by the best medical schools could here be taken for the maximum. Finally, the additional year of clinical experience in the schools would take the place of most of the usual courses in the hospital and dispensary, so that almost half of the second three years would be left for psychology, paidology, education, sociology, school hygiene, gymnastic sports, etc., the amount of each being dependent upon the student's choice among the four special lines above named: medical inspection, clinical child psychology, physical training and school sanitation. Throughout the course time would be saved and effectiveness promoted by never losing sight of the professional nature of the courses. Physiology, pathology and bacteriology, as well as psychology and sociology, would have to be taught in their relations to the ultimate work to be done, not as so many unitary and complete sciences. Even the first three years ought to be conscious of the professional end.

A school health officer, the product of such a school, would be of far greater service to education than is the usual school physician and would probably be worth more to society in the long run than a dozen well-trained practitioners. At least one such specialist in child hygiene is needed for every 2,000 school children. California needs 200, the United States at least 7,000. What university will be the first to undertake their production?

Finally, could men be found in sufficient numbers who would be willing to pay the price in time and strenuous effort involved in such a training for the modest remuneration the schools would offer? No reason appears why there should be any dearth of candidates. The pay frequently ranges from $2,000 to $3,000 per year and occasionally goes as high as $4,000. Medical inspection, though spreading at a tremendous rate, is still new with us, and doubtless as the profession becomes more specialized and more standardized it will receive as well as merit higher remuneration. As things are, it compares not unfavorably with professorships in colleges and normal schools, for which we have a constant oversupplying of young Ph.D. candidates willing to serve an indefinite period of apprenticeship as underlings, if only the coveted promotion with permanency of tenure can be reasonably hoped for in the end. Indeed, the rising young profession compares in its rewards not unfavorably with the practise of medicine itself, thanks to what Flexner calls the "enormous over production of physicians."

THE FOUR PERIODS IN THE DEVELOPMENT OF THE MODERN ZOOLOGICAL SYSTEM

By Professor H. S. PRATT

HAVERFORD COLLEGE

IN 1758 when Linnæus published the epoch-making tenth edition of his "Systema Naturæ" the science of zoology was in a backward condition, having made but little progress for a long period of time. Some important advances, it is true, had been made by the generation immediately preceding that event. Trembley and Peysonnel had proved the animal nature of *Hydra* and of corals; Linck and Klein had increased the knowledge of the obscure group of echinoderms; Réaumur had continued the brilliant researches of Swammerdam on insects. The discovery of microscopic animals, also, in the preceding century, had opened up new vistas, into which, however, the scientists of the day saw as yet but dimly. Zoology was still, notwithstanding these things, a very crude descriptive science, in which but few fruitful attempts at comparative or philosophical studies had been made.

The cause of this failure to progress rapidly was not the lack of able and earnest zoologists in the preceding ages or even the absence of new discoveries, but the chaotic condition of the zoological classification and nomenclature, which stood in the way of the recognition of the true relationships of animals. A chaos could not become the basis of a system of philosophy. When thus in 1758 Linnæus introduced his fully developed binomial system and arranged all the animals then known to science according to its rules into classes, orders, genera and species he provided the key which should unlock the mysteries of zoology as a science, and disclosed the wonders it contained.

The essential feature of this system and that which was new at the time was the giving to each species of animals of two names, instead of one, or of several, one of which was the specific name and the other the name of the next higher subdivision in the classification, the genus. The other important features were the precisions of the terminology employed, which enables the author to characterize a species in a few words, and the natural arrangement of the classification in which the position of each species indicates the degree of its genetic relationship to all the others.

It is true that predecessors of Linnæus had anticipated many features of his system. The idea of a species was already well fixed before his time and efforts were made to characterize those then known and

the new ones which were constantly being discovered. But the names given were often complex and cumbersome and no uniformity existed between the systems of terminology of different authors. Also the custom of giving two or more Latin names to a species was frequently in vogue, but a binomial system, with the definite relation of the specific to the generic name, was new. The genus, which gives the clue to the natural affinities of the animal, was peculiarly Linnæus's invention.

Attempts had also been made by Ray and Klein and other advanced thinkers to form a system which should express the natural relationships of animals, but such attempts were generally not understood or followed and most authors still employed unnatural methods of arranging them. Many still followed Pliny and grouped animals according to the environmental conditions surrounding them, placing those together having similar methods of life, as land animals, fresh-water animals, marine animals, flying animals, etc. Within each group the species were often arranged in alphabetical order.

Linnæus's system was very quickly accepted by the scientific world and went into universal use, and modern zoology may in a very real sense be said to begin with the year 1758.

So radical, however, was Linnæus's reform that neither the superiority of his system nor the simplicity of his terminology would probably have been sufficient thus to procure its adoption if they had not been proposed by a man of his great fame and commanding position in the world. Linnæus was considered by his contemporaries, because of his numerous and important contributions to science and his eminence as a teacher in the University of Upsala, as the greatest naturalist of all time. His importance was indicated by the phrase in vogue: Deus creavit; Linnæus disposuit.

The immediate acceptance of the Linnæan classification had the same effect upon the study of animals and plants in his day as that of Darwin's theory of natural selection had almost exactly one hundred years later. It gave a tremendous impetus to every branch of biological investigation and started a new era. Systematic zoology, morphology, physiology and experimental zoology all attracted able investigators who studied them with feverish activity. Comparative studies first became possible, as now the facts of the science were for the first time arranged in something like an orderly and natural manner, and the next generation saw the rise of the sciences of comparative anatomy, paleontology and comparative embryology, and also the first modern speculations on the blood relationships and the evolution of living things.

All these things gave a new importance to zoology and raised it from the position it had occupied of a mere annex to medicine to the dignity of an independent science.

Linnæus divided the animal kingdom into six classes: Mammalia,

Aves, Amphibia, Pisces, Insecta and Vermes. The knowledge of this last class, which included all invertebrate animals except the arthropods, was in a very confused state, and one of the chief objects of the many able zoologists of the generation immediately following him was to remedy this condition. The men whose services were greatest in this direction were O. F. Müller, Lamarck and Cuvier. In 1794 Lamarck first distinguished the vertebrates from the invertebrates and subdivided the latter group into the five classes of Mollusca, Insecta, Vermes, Echinodermata and Polypi. Thus a long step was taken towards modernizing the system and this early effort of Lamarck may be said to be the first modern classification of animals. He, in his later works, further subdivided the invertebrate types until he had ten, the fundamental idea at the basis of his classification being that the various groups of animals constitute a single ascending series which begins with the lowest and ends with the highest. This principle of the unity of the type found a wide acceptance among the naturalists of that time and was based upon the law: Natura non facit saltum.

In 1812 Cuvier published his division of the animal kingdom into four branches or types and in 1817 his great work "Le Règne Animal" which established the second great reform of the system and was destined to exert an influence only second to that of Linnæus's "Systema Naturæ" upon the study of animals and the development of the system. In these works Cuvier controverted the principle of the unity of type among animals and taught that instead of one four distinct and permanent types prevail. It was upon these four types that he based his four fundamental branches of the animal kingdom: Vertebrata, Articulata, Mollusca and Zoophyta or Radiata.

A comparison of this classification with that of Linnæus will show what a tremendous advance had been made in the development of the system in the half century separating them. The group of animals which had benefited most in this general advance was probably the Mollusca, which was Cuvier's special field of research. The lowest group in Cuvier's system, as that in Linnæus's, was the one about which the least was known, the Zoophyta or Radiata being made up of several distinct and heterogeneous groups of animals which bore no near relationships to one another.

This condition led to an active investigation during the generation immediately following of all the lower animals and a very large number of works of fundamental importance appeared. Rudolphi studied the parasite worms, Tiedemann and L. Agassiz the anatomy and Johannes Müller the development of echinoderms, Ehrenberg the microscopic animals, Eschscholtz, Sars and others jellyfish and polyps. The knowledge of these two latter groups was also very much extended as the result of various scientific expeditions which were sent out by

the French, English, Russian and American governments to different parts of the world, especially to the tropical oceans. Of these voyages perhaps the most interesting were that of the Russian ship *Rurik* from 1818 to 1820, in which Chamisso and Eschscholtz went as naturalists and discovered the alternation of generation of *Salpa,* that of the English ship *Beagle* between 1831 and 1835 with Darwin as naturalist, and the American expedition under Captain Wilkes between 1838 and 1842 with James Dwight Dana as the principal naturalist.

The influence of all these investigations, and also of the newly established cellular theory of the structure of plants and animals, on the development of the zoological system led to the third great reform of the latter. In 1845 von Siebold subdivided Cuvier's fourth type, the Zoophyta or Radiata, into three types or phyla, the Protozoa, Zoophyta and Vermes, confining thus the term Zoophyta to the truly radiate animals. He also broke up Cuvier's second type Articulata, removing the Annelida to the new phylum Vermes and creating another new phylum for the Crustacea, Arachnida, Myriapoda and Insecta which he called the Arthropoda. Two years later R. Leuckart broke up the Zoophyta, subdividing it into the phyla Echinodermata and Cœlenterata, and emphasized the isolated position of the Protozoa, and a little later Milne-Edwards added still another new type or phylum, the Molluscoidea, in which he included the Bryozoa, Brachiopoda and Tunicata. The animal kingdom was thus in 1850 subdivided into eight phyla, the Protozoa, Echinodermata, Vermes, Arthropoda, Molluscoidea, Mollusca and Vertebrata, an arrangement which is still found in many text books.

Darwin's "Origin of Species" was published in 1859 and the fourth and last important reform of the zoological system of classification was the direct consequence of the doctrines therein promulgated. The theory of the common descent and blood relationship of all animals which Darwin taught was at variance with Cuvier's theory of fixed types and in harmony with Lamarck's theory of the essential unity of the animal kingdom, and was first employed by Haeckel as the basis of a system of classification. In 1877 he called attention to the need of placing the entire system on an evolutionary basis and at the same time subdivided the animal kingdom into the two great groups of the Protozoa and the Metazoa, and the latter into the two great groups of the Cœlenterata and the Cœlomata. In still more recent times other authors, notably Hatschek, following Haeckel's lead, have carried the subdivision still further on the same basis. The old idea of types, however, has a very tenacious life and is still the basis of the classification of animals in most text-books—and probably rightly so. For most animals, notwithstanding their ultimate relationships with one another, can as a matter of fact be grouped in a number of distinct types or

phyla, each of which has a characteristic plan of structure. Cuvier's belief, however, that these types are fixed and isolated creations, has long since been abandoned.

Very important has been the formation in recent times of the phylum Chordonia or Chordata, which brings under the same subdivision all the animals possessing the essential characteristics of the vertebrate type. The formation of this phylum has been due to the fundamental researches of Kowalevsky, who in 1866, 1867 and 1871 gave the first detailed and accurate description of the anatomy of *Balanoglossus* and also the first detailed accounts of the embryology of ascidians and of *Amphioxus*, showing that these animals are related to one another and to vertebrates. The term Chordonia was introduced in 1874 by Haeckel to include the Tunicata, *Amphioxus* and the Vertebrata and the terms Urochorda and Cephalochorda by Lankester in 1878 for the Tunicata and *Amphioxus*. In 1884 Bateson, on the basis of his researches on the American form *Balanoglossus aurantiacus*, added the Enteropneusta to the Chordata and proposed the term Hemichorda.

The system of zoological classification was thus fixed some twenty or thirty years ago and has undergone no important changes in its larger features since. This is not true, however, of many of the subordinate and smaller of its groups, the arrangement of which changes from time to time as the knowledge of the relationships of the animals composing them increases. We find this to be especially true of certain low animals which seem to be isolated side branches of the ancestral tree, the origin of which from the main stem is still obscure.

Each of these four distinct periods of reform of the modern zoological system has been inaugurated by one or two eminent men of great constructive powers who have been able to see deeper into the significance of facts than their predecessors and contemporaries and to interpret rightly those which they have gathered. The first reform was started by Lamarck and the second by Cuvier, the third by von Siebold and Leuckart and the fourth by Darwin and Haeckel.

FLORENTINO AMEGHINO

By Dr. W. D. Matthew
AMERICAN MUSEUM OF NATURAL HISTORY

IN the death of this distinguished paleontologist science has sustained a heavy loss. Our knowledge of the splendid succession of fossil mammalian life in the Argentine is due principally to the work of Ameghino. A collector and explorer whose energy and enthusiasm no handicap of opposition and poverty could overcome, a student of immense learning and keen insight, a writer and controversialist of extraordinary facility and dialectic skill, a broad thinker and daring speculator, above all a man of high ideals and great patriotism, his life and achievements are well worthy of admiration and respect.

Ameghino seems to have interested himself in fossils from boyhood. In 1880, while still, it would seem, in the early twenties, he had already spent ten years of his life in collecting fossil mammals in the Pampean formation in the vicinity of Buenos Aires, and especially in searching for evidences of man contemporaneous with these extinct animals. His conclusions as to the antiquity of man had received notice in the local journals as early as 1875, but had failed to secure the endorsement of the heads of the two great Argentine museums. Failing this endorsement at home, he sought to secure it abroad, and in 1878 exhibited at the Paris Exposition a great collection of archeologic and paleontologic remains. (The fossils were purchased by the late E. D. Cope and later came into possession of the American Museum of Natural History in New York.) Fortified by the support received abroad, Ameghino published in 1880–81 a two-volume brochure entitled "La Antiguedad del Hombre en La Plata," in which his views were set forth in full, together with a history of the controversy.

In succeeding years his time was given more and more to researches in the older formations underlying the Pampean, and to the collection and study of the wonderful mammalian faunæ which they contained. To explore these formations, lying mostly far to the southward, 500 to 800 miles from Buenos Aires, involved long expeditions on the part of Ameghino's younger brother Carlos, the elder brother remaining at home to earn the necessary funds for his own and his brother's support through a small stationer's shop which he kept in La Plata. Year after year these expeditions continued, and their results were published by Florentino in a flood of descriptive and controversial papers, amazing

FIG. 1. PORTRAIT OF FLORENTINO AMEGHINO, October, 1910.
Courtesy of W. J. Sinclair.

in volume, learning and acrimony. In 1889 he published a revision of the fossil mammals of Argentina in two large quarto volumes abundantly illustrated. During thirty years of work Ameghino described over 500 new genera, with probably some thousands of species of fossil mammals.

These papers made known to science a whole new world of animal life. The Tertiary mammals of South America were as different from those of the rest of the world as is the modern Australian fauna, and for most of our knowledge of them we are indebted to Ameghino. Besides the Santa Cruz with its wonderful riches of fossil mammals, he described a series of older faunas no less interesting. That so much should be accomplished by one man is remarkable enough. It is far more remarkable that he should achieve so much in spite of straitened means, and bitter official opposition, which he had, it must be admitted, brought upon himself by his vehement, combative and controversial

spirit. Some of his work, indeed, appears hasty and ill-considered, and its value seriously marred by a partisan and contentious maintenance of theoretic conclusions which most paleontologists have found it impossible to accept. Ameghino regarded the age of the later formations of Argentina as much greater than his confrères in Europe and North America could admit, and maintained views in regard to the phylogeny and derivation of the Tertiary faunæ, which, however skilfully defended, are not likely to find acceptance. But these peculiarities of theory and temperament should not blind us to the immense value and interest of his discoveries, nor to the vast learning and indefatigable industry with which they were brought before the scientific world. Nor should they prevent due meed of admiration to his enthusiasm and energy and sincere love of science. It is pleasant to record that even in his earlier years he had won his way to the high respect and honor of his fellow citizens and to an admittedly high standing abroad. He occupied for a time the chair of zoology and comparative anatomy in the University of Cordoba, and in 1886 was appointed secretary and subdirector of the La Plata Museum, but resigned this post two years later owing to differences with the director, Señor F. P. Moreno, and for ten or twelve years afterwards seems to have held no important official positions. In 1902 when the directorship of the Museo Nacional of Buenos Aires became vacant, Señor Ameghino was appointed to this honorable post. Under his direction the museum has shown great vigor and activity, while his researches bore fruit in a series of publications, now

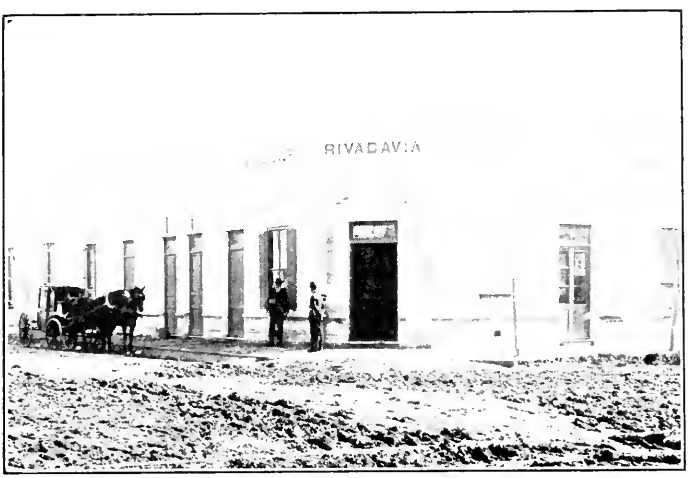


FIG. 2. THE "RIVADAVIA" STATIONER'S SHOP IN LA PLATA.

Courtesy of Professor W. B. Scott.

From the management of this business Ameghino secured the means to carry on his great researches in Argentine paleontology, and to maintain numerous expeditions by his brother Carlos into central and southern Patagonia.

abundantly illustrated, describing new discoveries and supporting and elaborating his stratigraphic and phylogenetic views.

His untimely death in August, 1911, is stated to have been due to blood poisoning from a neglected wound.

Through the courtesy of Professor W. B. Scott and Dr. W. J. Sinclair I am enabled to illustrate this notice with a portrait of Dr. Ameghino, and with views of the shop which supplied the funds for his explorations and the little workshop and study where his collections were installed and the greater part of his monumental researches were

Fig. 3. Ameghino's Workshop and Study at the Back of His Stationery Store in La Plata.

Courtesy of Professor W. B. Scott.

Packing cases stacked against the walls and in every available space served to accommodate the boxes of fossils, and rough deal tables to lay them out for examination and study.

carried on. There is something peculiarly affecting and inspiring in the picture of this great paleontologist, maintaining through all these years of straitened circumstance a record of splendid achievement, in a field which beyond most others is supposed to require ample means in order to accomplish much that is worth while. For the most conservative of paleontologists will accord to him a record of accomplished work equalled by few of his confrères in amount and importance.

Time will show how much of Ameghino's contribution to paleontologic theory will stand. But, right or wrong, his challenging of many accepted views has compelled a reconsideration and more careful sifting of the evidence upon which they are based, which can not but be bene-

ficial, whatever conclusions it leads to. In this field he stood forth as the chief exponent of doctrines maintained against strong and widespread opposition, forced into recognition and partial acceptance by the sheer vigor and energy with which he defended them, and the learning and skill with which he marshalled a tremendous array of evidence in their support. I, who disbelieve these views and have taken some share in combating them, can well afford to honor the ability and industry with which they were defended. Heterodoxy is of the life of scientific doctrine, the surest indication of its vigor and progressiveness. Only in decadence will our theories degenerate into a "body of geologic dogma," admitted to universal belief with universal indifference.

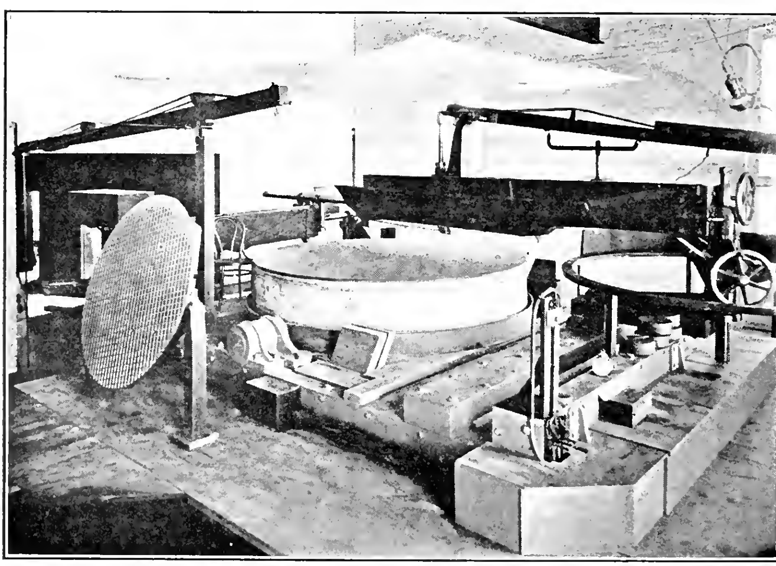
THE PROGRESS OF SCIENCE

TEN YEARS OF THE CARNEGIE INSTITUTION

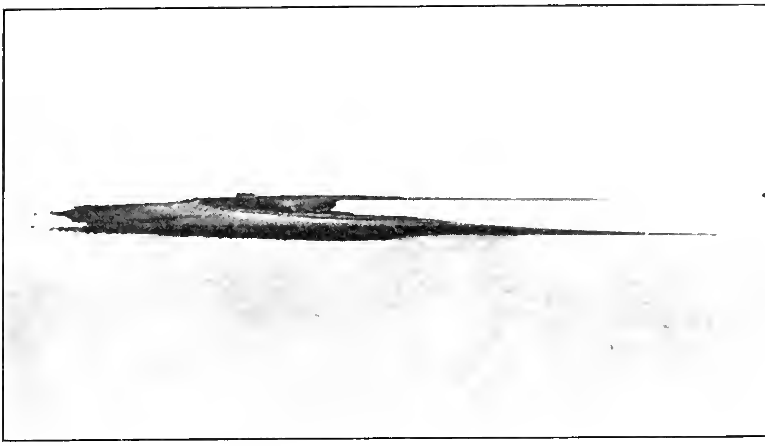
THE tenth yearbook of the Carnegie Institution of Washington is of special interest, as it records a further gift from the founder of ten million dollars and reviews the history of the institution for its first ten years. The endowment is now $22,000,000 in five per cent. bonds of the steel corporation, worth at least $25,000,000. The investment in property of the institution from its income is about $1,700,000 and there is a reserve fund of $250,000. During the ten years the cost of administration has been $400,000, of publication $300,000, and the sum of $4,000,000 has been applied directly to research. There have been published 201 volumes under 156 different titles.

The Carnegie Institution has definitely adopted the policy of devoting its income to the support of its own departments rather than to attempting to conduct an emergency fund for research. Some minor grants and research associates are maintained, but these also are semi-permanent in character, but few new special appropriations having been made recently. Last year about $500,000 was devoted to the ten departments of the institution.

The president states that the last fiscal year was the most fruitful on record for the ten specially organized departments of research. The solar observatory has now four telescopes—two tower telescopes, a horizontal 30-inch reflector and a 60-inch equatorial reflector. It has proved impossible to obtain a perfect cast for the 100-inch telescope, but the disc supplied by the French founders is being ground in the hope that the flaws will not interfere with its accuracy. The meridian determinations of stellar positions at the



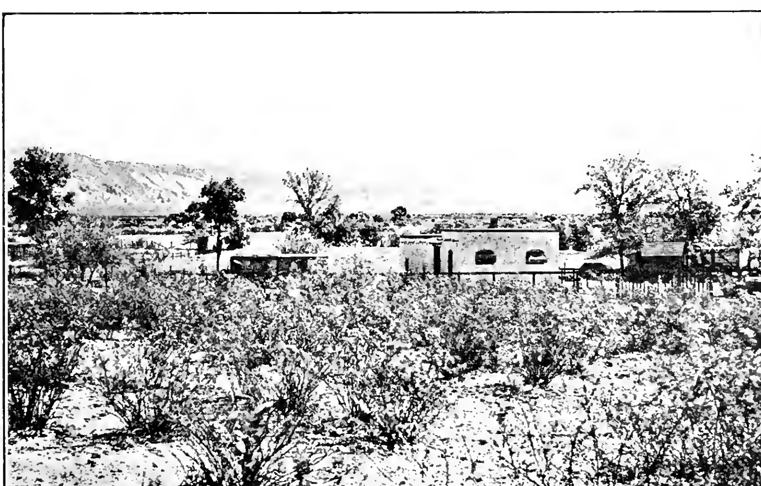
THE 100-INCH DISK ON THE GRINDING MACHINE.



Goose Island.

temporary observatory in Argentina have been completed. The non-magnetic ship *Carnegie* has traversed some 25,000 miles, measuring magnetic declination at 252 different points. The Geophysical Laboratory has continued its work on the chemical and physical problems presented by the materials of the earth's crust. To the work in astronomy and geophysics the institution devotes considerably more than half its resources.

The nutrition laboratory and three departments devoted to the biological sciences each receive appropriations of somewhat over $30,000. The Desert Botanical Laboratory has found an interesting problem in the results following the drying up of the Salton Sea, and has carried on researches on the effects on plants of altitude, dryness and other factors. The Department of Marine Biology has constructed a yacht, named in honor of the founder of the Naples Botanical Station, which enables it to carry on work



Scene at the Desert Laboratory.

in addition to that undertaken on the Tortugas. The Department of Experimental Evolution has, among other work, collaborated with the Eugenics Record Office in the study of human heredity, constructed a vivarium for cave life and used Goose Island to study the changes a domesticated species undergoes in becoming feral.

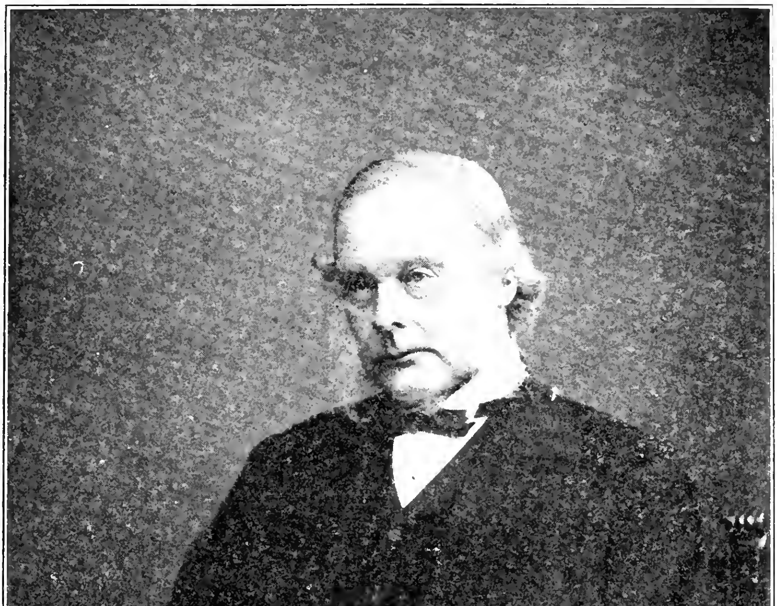
Endowed institutions for research are of vast importance for the progress of science. Under existing social conditions investigation can not be undertaken as an independent profession. The sales of the publications of the Carnegie Institution are less than one per cent. of the cost of the work which they represent. It is necessary that society should in some way pay for the research work which is of benefit to society as a whole, but can not be sold to an individual. In Germany investigation has in the main been carried forward in connection with university chairs, and during the nineteenth century remarkable results were obtained with a small expenditure. In England much of the most important scientific work has been produced by men having inherited wealth. In this country our universities have not yet equalled those of Germany in their productiveness, and we have but few amateurs.

The United States has, however, taken the lead in the amount of scientific work done under the government, and the two foundations for research endowed by Mr. Carnegie and Mr. Rockefeller have larger resources than those of any other nation. After the efflorescence of the medieval universities there was a period in the seventeenth and eighteen centuries during which the academies of sciences and the newly-established observatories, museums and botanical gardens became the most important centers of research. Perhaps the institutions endowed for research will in the twentieth century be the chief centers of scientific investigation. We may, however, hope that the universities, the research institutions, the national, state and municipal governments and industrial enterprises will unite to advance science and its applications. The United States has the largest natural resources of any nation, and in so far as these are used, the proceeds should in large measure be expended on scientific work, which will provide an economic equivalent for the fertility of the soil, the forests, the mining products and other natural resources which we are consuming.

LORD LISTER

In recording the death of Francis Galton somewhat less than a year ago, it was noted here that of the great men of science who gave distinction to the Victorian era only three remained —Hooker, Wallace and Lister. Hooker has since died at the age of ninety-four years and on February the eleventh Lister died at the age of eighty-four years. An English journal recently compiled a list of the ten greatest men of the world, and Lister would perhaps have been the name on which there would have been the most general agreement. Like Galton and Hooker, Lister had distinguished scientific ancestry, his father having been a fellow of the Royal Society, who, among many other services, gave us the existing compound microscope.

Joseph Lister was born at Upton in Essex on April 5, 1827. He received the degree of bachelor of medicine in 1847 and that of doctor of medicine in 1852 from the University of London. While house surgeon at University College Hospital he made researches on gangrene and pyemia. In 1856 he became assistant surgeon in Edinburgh Royal Infirmary, in 1860 professor of surgery at Glasgow University, in 1869 professor at Edinburgh University and in 1877 at King's College, London. He was created a baronet in 1883 and was raised to the peerage in 1893, with the title of Baron Lister of Lyme Regis. In Edinburgh he married the daughter of Professor Syme, the emi-



LORD LISTER.

nent surgeon, to whose chair he succeeded. His nephew is a leading man of science, but he left no children.

It was at Glasgow, where the infirmary was a hotbed of septic disease, that Lister, using the discovery of Pasteur that decomposition in organic substances is due to living germs which are descended from parents like themselves, applied the antiseptic treatment in surgery, an advance only paralleled by that of the discovery of antiseptics. It was not an isolated discovery, but was preceded and followed by important researches, which led up to it and perfected it. Perhaps no one else has accomplished so much as Lister for the relief of suffering and the prevention of premature death.

SCIENTIFIC ITEMS

We record with regret the death of Professor George Jarvis Brush, the eminent mineralogist of Yale University, and of Dr. Waldemar Koch, of the University of Chicago, known for his researches in physiological chemistry.

M. Lippman has been elected president, and Professor Guyon vice-president, of the Paris Academy of Sciences.—The Academy of Sciences at Bologna has awarded the Élie de Cyon prize of 3,000 lire to Professor E. A. Schäfer, of Edinburgh.—Among the British honors are knighthoods conferred on Professor W. F. Barrett, F.R.S., formerly professor of physics in the Royal College of Science, Dublin, and Professor E. B. Tylor, F.R.S., emeritus professor of anthropology in the University of Oxford.—It is proposed to have painted and to present to the American Philosophical Society a portrait of its president, Dr. William W. Keen, who, on January 19, celebrated his seventy-fifth birthday.

THE POPULAR SCIENCE MONTHLY.

APRIL, 1912

ON THE NEED OF ADMINISTRATIVE CHANGES IN THE AMERICAN UNIVERSITY

By Professor GEORGE T. LADD

YALE UNIVERSITY

IN the first of a series of articles on the higher education in this country, which were published in *The Forum* during the years 1902 and 1903, I designated the true functions of a great university as "chiefly these three: (1) The highest mental and moral culture of its own students; (2) the advancement, by research and discovery, of science, scholarship and philosophy; (3) the diffusion, as from a center of light and influence, of the benefits of a liberal, genial and elevating culture over the whole nation, and even over all mankind." On raising the question whether the universities of the United States had up to that time discharged these functions in a manner commensurate with their opportunity and with the demands made upon them by the size of their faculties and the wealth of their endowments, it seemed evident to me that we were forced to the confession, "They have not." And while no small part of the causes for this confessed failure must be charged to the general public, with its ignorant or mistaken views in respect to the interests, values and ideals of the higher education, no small part of the blame attaches itself to the internal management of these same institutions and involves their presidents, faculties and trustees.

Within the past ten years there has been a growing dissatisfaction with the character and the workings of the system of administration still prevailing in our larger and wealthier collegiate and university institutions. It has been pointed out that, while this system was admirable in its adaptation and praiseworthy in its results as applied a half-century ago to the small denominational college, it is ill-adapted and far from praiseworthy in many of its results, as applied to the

indefinitely more complex and almost totally different conditions of the modern university. Particularly inept in its character and disastrous in its results—so it is claimed—is the relation which the president sustains to the different faculties of a great university, and to its trustees or corporation or other governing board. In too many instances, it is claimed, this relation interferes with the perfect understanding and cordial, intelligent cooperation, which should always be maintained between the faculties and the governing board. There can be no doubt that, among the men who know most about the secret working of the present system of university administration in this country, and who are best competent to pass judgment upon it, the need of *some* change is keenly felt; and if there is as yet too little unanimity of opinion as to what that change should be, there is a fairly uniform agreement that the time for a franker and fuller discussion of the difficult subject has fully come.

Before saying anything in consideration of the problem itself, I wish to define it—at least so far as this attempt is concerned—somewhat more carefully. In the first place it is evident that the scores of small denominational colleges are not to be reckoned in the same class with the larger private and state institutions which have some valid claim to the title "university." A constitution which worked on the whole so well for them in the older days may continue to work almost equally well under more modern conditions. In their case, the fundamental necessities are such that they can not become anything at all—not to say, anything great—without being for a considerable time under the almost unlimited control of one man, with a corps of a half dozen sympathetic colleagues who are subordinates. It must also be borne in mind, when urging the need of greatly modifying if not totally abolishing the office of president in the larger institutions, that the very importance of the personal element in the successful discharge of this office, can be converted into an argument which counts heavily in opposite directions. Certainly, the office of president in any one of these institutions, under the present system of administration, is no sinecure. He who accepts or holds it may not improperly claim sympathetic pity from his friends, and plead with them, if not with the public, to help him answer the question: "Who is sufficient for these things?" The answer would have to be: Few indeed are, by natural gifts or by training; and fewer—far fewer—of those who succeed by the current political methods in getting chosen to the position. And as in so many instances the final event makes evident, it would seem more fitting to regard the music and the ribbons, the pomp and the paraphernalia, of the inauguration ceremonies as consecrating a victim for a free-will sacrifice than as raising a deified monarch to a sort of imperial throne. It is neither becoming nor necessary to the argument to follow the example of a series of articles published not long ago by

one of our most influential newspapers and denounce the great majority of college and university presidents as habitually guilty of falsehood and selfish intrigue. Indeed, such a charge is to be convicted of the untruth of exaggeration. It is quite enough to point out that the accusation itself, accompanied by the fact that it could find admission to a respectable weekly paper and be so largely credited as it undoubtedly was, offers strong reasons for devising some system of governing our universities which shall help to remove the temptation on the part of any of its officers to resort to such means of carrying their measures; and so make the charge intrinsically impossible and absurd. We desire, then, to keep in the background all suspicion of indulging in personalities, favorable or unfavorable to particular persons, while treating freely of the person of the president, its power and relations to the true functions of the university, in the prevailing system of university government.

And now let us consider what are some of the more important objections to the workings of the form of administration almost universally in vogue. These may be all summed up in saying that, in many, if not in the majority of cases, it hinders rather than helps the smoothest working and most valuable results of a university education. At once we must plant ourselves squarely and immovably upon the proposition that all the legitimate work of the true university culminates in its teaching. From this it follows that all the acquisitions of the university are subordinate to the quality and force of its faculties. Such an "institution of learning" may offer fine and even luxurious dormitories, and a cheap and well-served dining-hall for its students; it may give them agreeable and even refining opportunities for social life; it may have expensive appliances and large and splendid fields for athletic sports and culture; but if it has not the sufficient number and right sort of men in its faculties, it fails just where success is most imperatively demanded of it. All these other advantages, *so far as the work of the university is concerned,* are entirely subordinate. All the other officers are the servants of the teachers. Good health is indeed of vital importance; but in securing it, to refrain from dissipation and to take an abundance of open air in unexhausting exercise, is vastly more profitable than the existing extravagances and absurdities of college athletics. Social life is indispensable for the best development of the human individual; but it is not best obtained in the saloons, or clubs, or even in most of the sodalities popular with university students. I repeat: Everything else must be kept subordinate to the efficiency of the teaching, if the university is to discharge satisfactorily its chief functions. But that I am pleading for no narrow conception of these functions, let me refer to the sentences quoted above. It then appears that, not the students alone who are gathered under her walls are the pupils

of the great and good university; her pupils are also the nation and the world.

What now are the principal obstacles which have stood, and are still standing, in the way of the most efficient discharge of their obligations to their pupils, to the nation and to mankind, by the institutions of the higher and professional education in the United States? If we confine our attention—as indeed our theme demands—to those obstacles which arise more strictly within the university circles themselves, we may say: On the part of the students, the chief are the vices of extravagance, lawlessness, superficiality and idleness. All these are, to an extent, difficult to determine, connected with the grosser vices of certain forms of dissipation. The obstacles arising from the existing form of administration, on the part of the trustees, are chiefly due to ignorance, indifference and a species of cowardice which too often takes the fashion of reluctance to oppose the president or the majority of their colleagues on the governing board, or even to inquire too curiously into the motives or the significance of the measures brought before them by their presiding officer. And, finally, the smooth and efficient discharge of the functions of the university are hindred by insufficient education, lack of didactic skill, tactlessness, indifference or low moral tone, in any or all of its several faculties.

It would by no means be fair to charge the deficiencies and vices of the student body to the administration of the university, whatever the exact form of that administration might happen to be. The particular list of vices mentioned above are the national vices. And no amount of painstaking or system of discipline can keep life in the university free from infection by its public environment. It is not at all clear for what proportion of the extravagance, lawlessness, superficiality and indolence of the students the university may justly be held responsible. And, of course, previous to prolonged experience it is difficult to prove that these vices would be minimized or better held in check by a somewhat radically different form of university administration.

Of late years, the presidents who have been wise at the beginning, or who have become wise through experience in the early period of their career, have been more and more inclined to leave most of the discipline of the students in the hands of the faculties, or of the appointees of the faculties, to which the various classes of the students belong. In a large institution, the less there is of the one-man-power discipline, on the whole the better. Especially is the president tempted by favoritism, prejudice, various kinds of fears and by personal or family or friendly sympathies, to act unwisely if any power of punishing or pardoning is left in his hands alone. It is a misfortune for him and for the institution even to seem to have any such power. Too often has the professor, on bringing forward the name of some member of his classes who had failed in his studies or cheated in an examination, been made by the

presiding officer, through the latter's anxiety to save some notable athlete or the scion of some family of wealth or high social standing, himself to appear the delinquent, either in the artifice of detecting cheats or in the art of teaching those that *will* not to learn if they can possibly help it. Even stronger than any of these other motives may be the desire of the individual officer, if he is the nominal head of the entire show, to be popular with the "boys" and with their parents, the alumni and other constituency of the institution. And so long as such a large proportion of these "friends" (?) look leniently upon, if they do not largely indulge themselves in, the practise of these same vices, how can any one lonely man stand against the multitude for firmness and due severity in discipline? But a body of men like the faculties, or their selected committees, in a great institution, is much more likely than any one man can be, to administer even-handed justice, tempered with reasonable mercy. While, then, I am by no means prepared to quote with unlimited assent the following declaration taken from a pamphlet, entitled "The Demoralization of College Life": "College presidents are not willing to enforce the law or even to allow it to be enforced when it will cause them to lose students, especially rich and influential ones." I am fairly confident in the belief that the total elimination of even the appearance of one-man power or influence would greatly improve the *morale* of the student body. And this *morale,* whatever is to be said about it as compared with other countries and earlier days in this country, is certainly quite too low at the present time. It can be raised, and that without any very severe difficulties; and it would, in no very long time, be raised, if the men in the university faculties who sincerely want to see it raised, were given a free hand. Perhaps they might not have the "nerve" at once so to check the extravagance of college athletics as to make it no longer possible to spend a half-million dollars on a single game of bootball; or difficult for the sons of impecunious teachers or country parsons to embarrass their parents by calling for a goodly slice out of their salaries, in order to attend in proper style a dance that rivals in magnificence a state-ball at Government-House in Calcutta.

But is not the present prevailing form of university administration the only one under which the trustees, corporation or otherwise named governing board, can successfully discharge their part of the administrative functions? In these days, universities can not grow in other respects unless they grow in their finances. And there is something appalling, even to the multimillionaire, in the remorseless appetite of the American university for an ever larger expenditure of money. The trustees by advising and assisting the president, and by answering generously to a certain obligation put upon, or gently hinted to them, when they are chosen to the position of trustees, are supposed to be under obligation to oversee the getting and the expenditure of the

required money. But the obstacles which they may, for the most part unwittingly, throw in the way of the efficient work of the faculties of the university are chiefly due to their ignorance of the principles and right methods of education, or to their indifference toward the supreme ends of education, or to their reluctance to criticize—much more oppose—the will of the president or the majority of their own body. Indeed, their position and their action quite too often corresponds to that of the trustees of some bank or other large corporation, who altogether too late wake up to find themselves convicted of conniving at some imprudent or illegal transaction on the part of the official whom they have trusted incontinently.

The vice of extravagance in administration is being distinctly fostered by the system at present prevailing in our larger and wealthier universities. Money is much too largely given to bricks rather than brains, to mortar rather than men. In other words, too large a proportion of gifts and of income is being spent on needlessly expensive buildings; too small a proportion on teachers and explorers of first-rate ability in the several faculties. It is only a partial, but by no means a sufficient, excuse for this vice (?) of extravagance to say that we are now in the brick (stone) and mortar stage of our educational development, and that, when we have provided a splendid and complete equipment of the material sort, *then* we shall be ready to turn our full attention to raising the intellectual and spiritual equipment. For the drift of our experience and the point of the argument for a change lies in the fact that the present system is working toward the degradation of the professorial office and the depreciation of the functions and the *personnel* of the faculties. The fallacy for the other chief argument for this sort of extravagance is less obvious. It is said—and truly—that it is easier to get large sums of money for fine buildings than for great teachers or for stimulating scientific research. In reply, it is not necessary to credit the cynical saying of Europe—although there is much evidence in its favor—that the real scientific work done in the scientific laboratories of the United States is in inverse proportion to their magnificence. Nor could any real friend of the American universities feel otherwise than pleased and grateful to see them equipping themselves with buildings sufficiently commodious for calculable future needs, of good academic architecture, but above all, of the highest serviceableness. But such a friend can not in the same way approve the building of luxurious dormitories, where only the wealthy can really afford to live with any show of an honest independence. The simplicity and severity of the student life, in this and other similar regards, in the public schools and the colleges of the great universities of England are in refreshing and suggestive contrast to the extravagances and class distinctions of republican America. And when, contrary to the good judgment of the teaching force, scores and hundreds of thousands of dollars are unnecessarily

spent merely or largely to glorify the administration as a notable "building era" in the life of the university, it would seem that the foundations of an argument were laid for giving the men who have the work of teaching and research in charge, a much larger share in determining such matters.

These things, however, are of minor importance compared with the way in which the present system works out, too often, in practise, as affecting the very delicate and important but now remote relations between the faculties and their governing board. So long as these relations are chiefly—not to say wholly—through any one man, there are almost sure to be misunderstandings, heartburnings over real or fancied wrongs, jealousies and suspicion of favoritism and of intrigues, even if this one man is equipped with an inconceivable breadth of culture and of variegated scholastic interests, mingled in due proportions with the wisdom of a Solomon, the self-sacrifice of an apostle, and the temper of an angel. A few university presidents have had naturally, or have acquired, enough of this adorable mixture to pass courageously and patiently through years in so trying a position, and at the last to emerge with a large measure of respect and some measure of affection from their colleagues in the different faculties. But there are not a few other cases where great and irreparable injustice has been done to individuals and no small mischief to the university through lack of an appointed means of securing trustworthy communication between the governing board and the faculties under their control, irrespective of the representations and the control of the president. If the inside history of the mistakes made and the wrongs committed in this way were fully written—and it is probably not desirable that it should be and quite certain that it never will be written—it would be spotted with scandals of the most astonishing character. For example, several years ago a distinguished professor in one of our larger universities, who had given the greater part of his life to its devoted and efficient service, was as a part of the business of a single meeting of the trustees dismissed without further trial from his place; and after the action was taken and inquiry was made as to its grounds, not one of the trustees could be found who was willing to assume any responsibility or to state the grounds on which the action had been taken; or indeed, whether the letter written by the president to the professor fairly and truthfully represented the intention of the trustees. Subsequently, a number explicitly, and all implicitly, admitted that they had been deceived by the president.

From the point of view which regards its morally deteriorating influence on the faculties, the present arrangement is equally unsatisfactory. The men of standing in the world of science and scholarship, and of a high sense of honor, will not willingly resort to the trustees, either as individuals or as a body, unless they are officially authorized or requested

to do so. Of all men, too, they are least likely to run to the president with either complaints or defences, or to take any measures to "make themselves solid" with him. If they are being undermined or traduced by any one, whether on the outside or among their younger and more ambitious and place-seeking colleagues, they are even unlikely to know anything about it, so busy are they in their own work; or if they do know about it, they are not unlikely to scorn to pay any attention to it. But if no action touching the professional standing of any member of the faculties could be taken on the initiative or recommendation of the president alone, there is little doubt that this kind of maladministration would occur much more infrequently.

Indeed, it would seem as though this one contention did not require prolonged or subtle argumentation. Granted even that "the cotton-mill policy" is suitable for the administration of a great university: yet the head of this form of industrial enterprise ought to be, as a "boss," no lest strictly limited than the bosses in other no more important or intricate industrial enterprises. This is the one thing that the labor unions are most vigorously and most righteously insisting upon—namely, that there shall be some adequate and trustworthy means of employers and employees coming near, in a frank and friendly way, to each other.

But of all the objections to the continuance without change of the present system of administration in the great universities, the most weighty and imperative is this: it is one of the most productive of the several causes which are working together to bring about "the degradation of the professorial office." That this process of degradation is really going on, I ventured to assert in one of the series of articles to which reference has just been made. The response which the assertion called forth at the time went a long way toward confirming the opinion. Careful inquiry into the history of the last decade of collegiate and university movements would, I am sure, show that the process has in the meantime not been checked. It is the rather to be feared that it has gone forward with a quickened pace. The causes of this process do indeed chiefly lie beyond and below the power of any form of management largely to control.

Let us briefly consider the case of the young man who decides to devote his life to a university career. The more intelligent and deliberate the decision is, the later it is likely to have come in the course of his secondary education. But under the working of the system of almost unlimited electives which has prevailed in our higher institutions of learning during the past half-generation or more, the candidate for a future professorship is almost certain to discover that he has neglected to lay the foundations of any particular subject solidly and thoroughly well. He knows no *elements,* as the elements of every species of science and scholarship must be known, in order to proceed

safely and with joy in hard work to its ever higher stages of study, research and discovery. But our intending professor can not go back into the fitting-school or into freshman year, and begin over again. He enters the graduate department. Here he has, with few exceptions, as colleagues in study, men who, like himself, are not well-grounded and who are unable or unwilling to submit to the prolonged and severe discipline which is necessary for the training of the intellectual athlete. He is prematurely set at "a problem" and works with an aspiring eye on the degree of Ph.D. That this description is not true alone of the few advanced students trained by the secondary educational system of this country, who are without serious purpose, I may cite the unanimous testimony of the professors and other officers at Oxford respecting the Rhodes scholars in general, as it was given to me on occasion of a recent visit there. They are, for the most part, fine, manly fellows, earnest in work and anxious to pick up whatever might seem fit for their advantage, but superficial in their attainments, eager to *specialize* minutely while as yet they know little or nothing thoroughly as to elementary matters in their chosen specialty, and restive under all manner of control, whether as touching manners, petty morals, the prompt keeping of appointments, or conformity to university regulations.

Now that our candidate is ready for his professorial career, how shall he get into a place which will at least give him a foot-hold for beginning a life-long race? He must be, as a rule, recommended by somebody (often some president) to some president, who will, if he thinks best, recommend him to the appointing board. This latter recommendation is usually equivalent to an appointment, although of late the sane custom of consulting some members of the faculty into which the candidate is to be introduced has begun to prevail. In popular parlance, he must push and be pushed. But every one who has had the long experience of the writer in such matters knows perfectly well that the willingness and skill to push one's self, and the vigor and success with which one is pushed by others, are quite as often in inverse as in direct proportion to the merits of one's case.

When all the preliminary stages are passed through, and the candidate has really the right to call himself professor—although the young ladies whom he used to meet at the summer resorts were wont to call him "professor" when he was in fact only a tutor or an instructor—unless he has a most self-sacrificing intellectual interest in his calling and a thoroughly ethical love for the work of the teacher, he finds that his position and its rewards are not at all what he fondly imagined they would be. His classmates who have gone into business or into the professions of law or medicine are in receipt of incomes two-fold or four-fold his own. They have a higher social standing; and those they have served with no higher degree of talents or of success are seemingly more grateful and ready in some form or other to show appreciation of the

services rendered in their behalf. But let him never mind. Perhaps, if he is a true man he does really not much mind. But what he can scarcely help minding is this: His whole career, and the reputation and influence which he has won by a life of self-sacrificing labor, may at any moment be in peril through the caprice, or cowardice, or ill-will of a single man, or of a little group of men who have influence with that single man. Then he will have the choice between a silent submission or an ignoble contest with a probably inglorious—albeit triumphant—ending.

This last and worst of all the many influences tending toward the degradation of the professorial office is definitely connected with the present system of university administration. One can not wonder, and one can scarcely blame, the younger generation if they neither have nor profess the same unstinted devotion for an institution as that which sustained their forebears during lives of self-denial, hard work and low living. They are in it for what they can get out of it, much more than their old-time predecessors were. They need not be at all so careful as their elders were about any shadow being cast upon their reputation for the most upright and austere morality; but they are almost sure to be more careful about standing in with the power that has most to do with appointments and promotions. For the question may at any time be thrust upon them: Which shall I sacrifice, my hard-won position or my highly prized spirit of manly independence?

Immediately following the consideration of the evils of the present system of university administration in this country comes the question: Can these evils be abolished or lessened by any feasible changes in this system? And on the heels of this question follows another: If changes are to be made, what shall those changes be? In treating these questions it scarcely needs to be said that, as a matter of course, no system of administration, to whatever purpose that system may be applied, can avoid encountering and in all probability collecting about itself, a host of embarrassments and of obstacles to its perfect working. Institutions that have developed as large and old universities have, even in this comparatively new country, in fact developed, can not be subjected to radical changes, suddenly, and on grounds of theoretical significance alone. But as I have already said, so obvious and important in their power to defeat the smooth and successful working of the highest functions of a great and good university have some of these evils grown to be, that the time has fully arrived for a frank and thorough discussion of the topics suggested by them. And this discussion may be entered upon with the conviction that some of these evils, and those not the least of them, are so largely due to the nature of a worn-out system, that by changing the system we shall lessen if we do not wholly extirpate them.

In order to point the direction in which changes are both needed and promising, as respects the present system of university administration

in this country, it seems to me that some fixed places of standing may be established. In closing this article I will mention the following as among the most important and perhaps they may be summed up in a tentative way, in this sentence: The administration of a large university requires for its most effective conduct two boards or bodies of men, which have largely different functions and for the most part a different *personnel,* but which are bound to cooperation for the welfare of the university by regularly appointed and trustworthy means of understanding each other's views, necessities, and measures enacted, and by a system of checks that shall operate in guarded ways to make each responsible for its initiative to the other.

Of these two boards which are necessary for the efficient administration of a large university, one should be chiefly responsible for its material affairs. For this reason it should be largely composed of men of sound business principles and experience; but also, as far as possible, of men possessed of a worthy knowledge of the needs and methods of a modern university education and with devotion to high educational ideals. There would seem to be no valid objection to, but much valid reason in favor of, having a small minority of this board chosen from the different faculties of the university. Why should not a professor of business law, a professor of economics, and a professor of architecture or engineering, be useful members of such an administrative body? Even a professor of ethics, if one could be found who combined a firm grasp on moral ideals with a fair amount of practical wisdom, might sometimes serve as a valuable control in the performance of the legitimate functions of the trustees of an institution of the higher education.

It is unnecessary to emphasize the fact that the business administration of a large educational corporation requires the same trained staff of competent and responsible assistants—treasurer, cashier, clerks, etc.—which are required by any other business corporation of equal magnitude; and these paid assistants should be held to as strict account in every respect as that which prevails in the best organized business corporations. If, besides the gifts which are solicited or directed to the endowment or income of a well-organized and well-administered university through the free-will devotion of its trustees, faculties, alumni and other friends, there is pressing need for yet more, it would always be within the province of this board to call to its help especially selected agents for meeting such need. But however the details of collecting and distributing the material resources of the university are managed, and whatever the success which attends their management, it should never be lost out of mind that all their value consists in the efficiency with which they minister to the real ends and promote the realization of the true ideals of a great and good university. These are not in any way necessarily connected with the glorification of any one man or of any

single administration as a money-getter or a builder of magnificent buildings.

The other arm of administration, which ought to be equally strong and self-respecting and independent within its own appropriate sphere, must be wielded by the faculties. But not by them as acting all together, or as all acting equally in any one faculty, or as acting in an unorganized and unrestricted way. The same process which has tended toward the degradation of the professorial office has increased the danger of something resembling mob rule, if every teacher stands on equal terms with every other, in a great university. Yet, in general, the educational policy, matters touching the curriculum, and all the discipline of the student body, as almost a matter of divine right, whether or not by custom or by statute, belong to the men whose craft and experience is in lines of education. And while they should always be thoughtfully considerate of the judgment of their employers, and are quite of necessity dependent upon them in the matter of their salaries and of the equipment allowed for the prosecution of the work of their departments, they should be so related to these employers as to be delivered from all feelings of fear, or wish or chance to curry favor, in the discharge of their functions as teachers and explorers of truth.

In saying this I am far indeed from advocating an unrestricted license for the individual teacher, or even for the whole of the teaching force. The management of the more strictly educational affairs of each one of the separate faculties would, in general, best be left to each one of these faculties. And, indeed, so far as the professional schools of law and medicine are concerned, this course is customarily adopted. In the faculties of these schools there is customarily a moiety of strong and independent men, who can readily take care of themselves if obliged to leave their positions; and while ready to hear and heed advice (or, at least, they ought to be so), they are not ready to take orders unquestioningly from the president or from the corporation. But the same thing ought to be true of all the faculties. When, however, these faculties are large and largely composed of young and inexperienced men, as is sure to be the case with the faculties of the undergraduate schools of a great university, their internal control can not be safely committed to the entire body—share and share alike, as it were. It can not be democratic; it must be aristocratic. And this arictocracy would have—so it would seem—to be selected by joint action of the full professors and the trustees. The method of its fixing might be adapted to the circumstances and the needs of the particular institution. Once fixed, the advice and cooperation of the entire body of officers, of every sort and grade, might be invited or commanded, but the final control of educational matters would rest in the authority of this aristocracy, with the aid of those to whom they might see fit to delegate any portion of it. And, finally, for matters affecting immediately the scholastic interests

of the whole university, and for adjusting differences and conflicts touching educational interests between the different departments, a university council is a most feasible expedient. Only be it understood that such a council should be no sinecure, or body designed to assume a show of responsibility while actually having little power to check intrigues, to judge intelligently and righteously, and to act with something more than a mere shadow of influence or authority.

Most important of all the improvements for which we might have a fair measure of hope, if something like the suggested changes could be inaugurated and fairly and thoroughly tested in the administration of our greater and older universities, would be the improvement in a good understanding and in reciprocal confidence and in effective cooperation, between the board of teachers and the board of business management, between the professors and the trustees. In the lack of knowledge, of confidence and of cooperation, most of the embarrassments, difficulties, failures, and scandals connected with the present system of university administration in this country undoubtedly arise. And perhaps in the majority of these cases they arise from or center about the action of the president. It will be noticed that the scheme tentatively proposed in this article does not *necessarily* call for any president. And, indeed, we may boldly ask ourselves, Why should there be any president, if by this title we mean to cover the office of any one man combining within himself, *even apparently,* all the functions belonging to this name in the days—and, if you please, even now—of the small denominational college? A figure-head to represent the university at home or abroad on occasions of peculiar import and corresponding grandeur can easily be appointed, either with a three-years' tenure or for each special occasion.

Doubtless many difficult problems will arise and await a speedy or more remote solution, in the way of any institution which attempts to inaugurate the needed changes. Doubtless, too, the particular character of the changes enacted would wisely vary in different cases. In the cases of universities under state control, every thing could scarcely be arranged in the same way as in the cases of the private institutions. Doubtless, again, the effect of change upon the alumni and the public at large would have to be seriously taken into the account. But neither the public, nor the alumni, nor the trustees, and perhaps not even the presidents of these institutions, realize how deep is the dissatisfaction with the existing system, how urgent, if not loud, is the call for a somewhat radical change. At any rate, it is high time that the problems afforded by this system should be frankly and boldly faced; high time that the disadvantages should be announced, if not at once corrected.

SCIENCE IN THE SERVICE OF HIGHWAY CONSTRUCTION

By CLIFFORD RICHARDSON, M.Am.Soc.C.E.

NEW YORK CITY

IN a popular sense, a road is a means of communication by vehicle between different localities. To the citizen who ordinarily uses it, aside from considerations of its aspect and surroundings, the condition of the surface and the ease of traction over it have been the main considerations. He has given little thought to the manner in which it has been constructed and has been, usually, quite indifferent to or ignorant of its cost originally or of that for its maintenance. As the use of the automobile has become so general there has recently been a very decided change in this respect. The movement for good roads has arisen and a general interest in the subject has developed. In what follows an attempt will be made, for the benefit of the general reader, to outline the development of the modern methods of highway construction, and to show how science has aided therein.

The art of highway engineering, that is to say, of the construction of roads, was considered to have been developed to a high degree of perfection at the end of the last century, as evidenced by the magnificent system of broken-stone roads which were in existence at that time in France, more especially, and in England and other foreign countries, while in the United States successful systems of broken-stone roads had been begun in New Jersey, Massachusetts, Connecticut and a few other eastern states. Roads of this type, when constructed by engineers of experience, with suitable stone, of a proper thickness and with a sufficient foundation, properly drained, and when continuously maintained, were found to be adequate to support the severest kind of travel to which they were subjected at that time, at a cost which was not an excessive burden on the state or the taxpayer. The traffic consisted almost entirely of horse-drawn vehicles and the road surface was resistant to a degree which would carry this traffic without rapid deterioration. Roads of this character were known as water-bound macadam, a name derived from their resemblance to the broken stone roads constructed in England by the celebrated highway engineer John Loudon Macadam in the early part of the last century. Briefly, water-bound broken-stone roads, of the highest type known in the United States, and the only form built until recently to carry heavy travel, are constructed as follows:

The grades of the road are carefully studied and laid out in the most favorable manner by an engineer so as to make it as level and straight as possible with due regard to the economics of the problem. Corresponding to these grades the subsoil foundation or subgrade of the road is constructed either by cuts or fills, so that its surface is at a depth below the surface of the road as it is to be finished corresponding to the thickness of the compressed material to be built up thereon. The subgrade must be so prepared, especially in fills, by the use of proper material and thorough rolling with a steam roller, that it is absolutely stable and rigid, and will not be thrown out of shape by frost. The preparation of the subgrade is one of the most important points in good road construction and, although it is purely a structural problem, it is too often neglected or passed over without sufficient consideration and care. It can be readily understood that the rigidity and wearing character of a road can be no greater than that of the subgrade which supports its surface.

Upon the subgrade the road itself is built, or a further foundation may be constructed upon it, if the conditions seem to demand it, that is to say, there are two types of broken-stone roads, one commonly called a macadam and the other a telford road. In the former the broken stone is placed directly on the subgrade and in the latter, from considerations of the character of the subsoil or of that of the traffic on the road, on a further foundation constructed, as described by Mr. Austin B. Fletcher, as follows:

> A satisfactory telford foundation may be made by placing vertically on a layer of gravel, 2 or more inches in depth, stones of fairly uniform size, not exceeding 10 inches in width, 6 inches in depth, and varying in length from 6 to 20 inches. The stones should be set on their broadest edges, lengthwise across the road, and wedged rigidly into position by smaller stones driven by mauls into the interstices between the telford stones. The projecting points should be broken off with stone hammers, the depressions filled with chips, and the telford rolled with a steam roller until it is true to the desired cross section.

The foundation, whether of the macadam or telford type, should be properly drained, since the presence of water softens the subsoil so that the broken stone is forced into it under pressure, weakening the road and destroying the shape of the surface. This provision is very generally neglected in the United States. In addition ditches or channels must be provided on each side of the road to remove the ground water collected by the drainage system and to take care of the surface water which is thrown off the road by the crown, or camber, and the grades.

Upon the subsoil or telford foundation is placed broken stone between shoulders of soil or other suitable material, to prevent its lateral displacement. According to Macadam the stone consisted of pieces of uniform size, about two inches in diameter spread to a depth of ten inches and then compacted by the traffic which passed over the

road. To-day quite a different procedure is employed. The stone is applied in two courses and in two sizes. The first or lower course consists of larger stone than that used for the surface, from an inch and a half to two and a half inches in diameter. It is carefully and uniformly spread to such a thickness that it has, when compacted, a thickness of from three to five inches, depending on the character of the foundation and that of the traffic which the road is to carry. The second or upper course, which forms the surface or crust of the road, is composed of finer stone, one half to one and a half inches in diameter, to a thickness of at least three inches when compacted. Great advances in highway construction have taken place since Macadam's day, in that steam rollers have been available for some decades for compressing and putting in place in a proper manner, the broken stone after it is applied to the foundation. Each course is rolled separately until it ceases to move under the roller.

After the compression is completed a binder or filler of much finer stone is spread over the surface, all of it passing an opening three eighths of an inch in diameter and a considerable portion being fine dust, for the purpose of filling the voids in the upper course of stone, closing up the surface and preventing infiltration of water through it. This is accomplished by the use of water, applied with a watering cart, which washes the fine material into the interstices in the stone. The road is then again rolled with the steam roller, to aid in forcing the filler into the surface, and to render it compact and waterproof. Skill is required in the manipulation of the roller to produce a surface of proper conformation and uniform density.

The method of constructing a water-bound broken-stone road, which has been described in a very general way, is still in use for work of this type, and was the only one employed up to the beginning of the present century, in building roads to meet the most trying conditions then existing. It was a very satisfactory form of construction and still is, under certain conditions and environment. The execution of such work was an art involving great skill and experience, but science contributed but little to perfecting it and placing it on a rational foundation, with the exception of methods of examining the character and availability, from this point of view, of the various rocks which are used in building roads, which were developed in France, and on a much more elaborate scale by the Massachusetts Highway Commission, and in the Office of Public Roads of the United States Department of Agriculture by Mr. Logan Waller Page, the present director of that office, who, with his assistants, has contributed largely to the application of science to the improvement of highway construction. These methods are of so much interest that they are worthy of description.

In determining the suitability of a rock for the construction of a

water-bound broken-stone road, its physical characteristics and its behavior under certain conditions are important. Before the development of means of determining these characteristics in the laboratory, the only way in which they could be arrived at was from observation of the behavior of the particular rock in a road when exposed to travel for a considerable period of time.

The important characteristics of a rock which enables one to judge of its suitability for road construction are (1) its resistance to wear or abrasion by impact, (2) its hardness or resistance to the displacement of its particles by friction, (3) toughness or resistance to fracture by impact, (4) the cementing properties or value of the rock powder or dust produced by attrition, when moistened, (5) porosity or capacity for absorbing moisture, the latter being closely associated, for the same kind of rock, with the specific gravity, and (6) the structure or size of the grain of the rock, the character of the minerals of which it is composed, and the extent to which these may have become altered by weathering, upon which all the other characteristics of the rock will depend.

The methods of determining these characteristics have been largely originated and developed in the Office of Public Roads in Washington, and are described in one of its bulletins, No. 31, as follows:

Percentage of wear represents the amount of material under 0.16 cm. in diameter lost by abrasion from a weighed quantity of rock fragments of definite size. It is determined in the following manner: The rock sample is broken into pieces that will pass through a 2.4-inch ring but not through a 1.2-inch ring, and after being thoroughly cleansed, dried and cooled, 5 kg. are weighted and placed in a cast-iron cylinder (34 cm. deep by 20 cm. in diameter) closed at one end and having a tight-fitting iron cover at the other. This cylinder is one of four attached to a shaft so that the axis of each is inclined at an angle of 30° with that of the shaft. These cylinders are revolved for five hours at the rate of 2,000 revolutions per hour, during which the stone fragments are thrown from one end of the cylinder to the other twice in each revolution. At the end of five hours the machine is stopped, the cylinders opened, and their contents poured into a basin, in which every stone is carefully washed to remove any adherent detritus. This abraded material is then thoroughly dried, and from the amount lost below 0.16 cm. the per cent. of wear is estimated.

Hardness is the resistance which a material offers to the displacement of its particles by friction, and varies inversely as the loss in weight by grinding with a standard abrasive agent. The test is made in the following manner: The test piece in the form of a cylinder about 3 inches in length by 1 inch in diameter is prepared by an annular core drill and placed in the grinding machine in such a manner that the base of the cylinder rests on the upper surface of a circular grinding disk of cast iron, which is rotated in a horizontal plane by a crank movement. The specimen is weighted so as to exert a pressure of 250 grams per square centimeter against the disk, which is fed from a funnel with sand of about $1\frac{1}{2}$ mm. in diameter. After 1,000 revolutions the loss in weight of the sample is determined and the coefficient of wear obtained by deducting one third of this loss from 20.

Toughness as here understood is the power possessed by a material to resist fracture by impact. The test piece is a cylindrical rock core similar to that used in determining hardness, and the test is made with an impact machine constructed on the principle of a pile driver. The blow is delivered by a hammer weighing 2 kg. which is raised by a sprocket chain and released automatically by a concentric electro-magnet. The test consists of 1 cm. fall of the hammer for the first blow and an increased fall of 1 cm. for each succeeding blow until failure of the test piece occurs. The number of blows required to cause this failure represents the toughness.

The cementing value, or binding power of a road material, is the property possessed by a rock dust to act as a cement on the coarser fragments comprising crushed stone or gravel roads. This property is a very important one, and is determined approximately as follows:

One kg. of the rock to be tested is broken sufficiently small to pass through a 6 mm. but not a 1 mm. screen. It is then moistened with a sufficient amount of water and placed in an iron ball mill containing two chilled iron balls weighing 25 pounds each and revolved at the rate of 2,000 revolutions per hour for two hours and a half, or until all the material has been reduced to a thick dough, the particles of which are not above 0.5 mm. in diameter. About 25 grams of this dough is then placed in a cylindrical metal die, 25 mm. in diameter, and by means of a specially designed hydraulic press, known as a briquette machine, is subjected to momentary pressure of 100 kg. per square centimeter. Five of the resultant briquettes, measuring exactly 25 mm. in height, are taken out and allowed to dry for 12 hours in air and 12 hours in a hot oven at 100° C. After cooling in a desiccator they are tested by impact in a machine especially constructed for the purpose. This machine is somewhat similar to that used in determining the hardness, and the blow is about the same, excepting that it is given by a 1 kg. hammer and the distance of drop does not exceed 10 cm.

The standard fall of the hammer for a test is 1 cm. and the average number of blows required to destroy the bond of cementation in the five briquettes determines the cementing value.

The specific gravity is the weight of the material compared with that of an equal volume of water, and is obtained by dividing the weight in air of a rock fragment by the difference of its weight in air and water. Given the specific gravity, the weight per cubic foot of a rock is found by multiplying this value by 62.5 pounds, the weight of a cubic foot of water.

The examination of a rock for structure, its mineral components and the degree to which it has become weathered, is carried out by preparing a thin section of such thickness as to be transparent under the microscope. Its characteristics are then readily determined by the methods employed by the petrographer for this purpose. The appearance of such a section, made from a trap rock of a kind used in the construction of a broken-stone road, is shown in an accompanying illustration, taken from the Bulletin of the Office of Public Roads, which has been referred to.

The application of the methods which have been described to the study of rocks for the purpose of determining their suitability and relative merit for road construction was the first contribution to and application of scientific methods to the subject. Before this road con-

struction was merely an art, more or less skillfully carried on, based on experience, but purely rule of thumb in its execution and not founded on any rational principles. With the application of scientific methods as a means of determining the character of the stone to be selected the building of a water-bound broken-stone road was placed upon a much more satisfactory and rational basis. Roads of this type, so constructed, especially in Massachusetts and under the supervision of the Office of

Fig. 1. Diabase (Trap).

Public Roads in other states, were, and are to-day, entirely suitable and satisfactory for carrying horse-drawn traffic. When, however, self-propelled or motor vehicles became an important part of the traffic which these sufaces have to sustain, the latter have been found to be entirely unsuitable for the purpose.

The automobile has introduced an entirely new element into the road problem, and one which can only be solved by the application of the scientific methods. It is in this direction that science has proved itself of the greatest service to the highway engineer.

The destruction of the surface of a water-bound broken-stone road by motor traffic is due, according to experiments conducted by the Office of Public Roads, to the shearing or grinding action of the tires of the rear wheels of cars, which under the impulse of the engine, revolve at a slightly higher rate than that corresponding to the movement necessary to conform to that of the car over the road. It thus acts like a grindstone and loosens up the fine material which is necessary to cement

the surface. This fine material in its loosened condition is picked up by the current of air produced by the rapid motion of the car and is blown away, forming the clouds of dust which is one of the most unpleasant features of the use of motor cars. Of course the greater the speed the greater the shearing action of the tires, the greater the amount of dust loosened and the greater the destruction of the road. As a matter of fact there is little or no damage done at speeds of less than thirty miles an hour. That the damage is due to the rear wheels alone is shown in instantaneous photographs of a car moving at ninety miles an hour over a water-bound surface. Practically no dust is to be seen about the front wheels while a cloud arises from the rear tires. If the commonly accepted theory that the destruction of the road surface is due to the suction of the rubber tires, there should be an equal amount of dust stirred up by both the rear and front wheels.

The present condition of affairs is still further illustrated by the statement of the Massachusetts Highway Commission in its 18th annual report for the fiscal year ending November 30, 1910, which follows:

> The fact that a macadam road will not withstand such travel (motor vehicles) was again demonstrated upon the piece of road that was built in Becket in 1909, around Jacob's Ladder, so called, where the commission constructed a long stretch of macadam road, using the best local stone available. The road was not open to travel until late in the fall of 1909, but before the first of July, 1910, the surface of the road had been torn up in many places by automobiles, and on the corners and curves deep ruts had formed. Consequently, when the road was less than a year old the commission was obliged to spend over $1,400 a mile in repairing it, putting it back into shape and applying a coat of asphaltic oil. When it is remembered that this road is in a sparsely settled country district, merely part of the main line between the Connecticut Valley and Berkshire County, and that nevertheless there is sufficient automobile travel to make oiling it an absolute necessity for its preservation before it has been used one year, it will be realized that some such treatment of macadam roads will have to be adopted over a large percentage of the state highways in the commonwealth. This treatment costs all the way from $500 to $1,200 a mile, according to the width coated, the length of haul, material available and the class and character of the bituminous binder that it is necessary or advisable to use.

The strongest evidence of the fact that motor travel has injured roads of the water-bound broken-stone type is the increase in the cost of their maintenance, both in this country and abroad, since they have been used by automobiles, in regard to which a few data, among the large number available, are of interest.

At a conference of the governors and chief highway officials of the New England states, called together at Boston by Governor Guild, of Massachusetts, in 1909, Mr. Harold Parker, chairman of the Massachusetts Highway Association, stated that

> Up to the year 1907 the cost per mile for maintenance of the Massachusetts state highways was not far from $100.

Since the advent of automobiles, particularly those capable of being operated at high speeds, it has become evident that $100 a mile a year is wholly inadequate for the maintenance of macadam roads, even if they be only of the width of the Massachusetts state highways, and that in order to keep such stone roads in perfectly good condition at least $300 a mile a year should be provided.

Figures in the possession of the Massachusetts Highway Commission show that about 53 per cent. of the destruction of state highways is due to automobiles. In seven counties near London, England, the percentage of increased cost of maintenance, due to automobiles, has been recently reported to be from 22 to 77 per cent., and this condition is probably more or less the same throughout England.

Mr. Compton, county surveyor of West Cornwall, England, reported in 1910 that in 41 counties the cost of maintenance of broken-stone roads had increased in ten years, since the advent of the self-propelled vehicle, forty-one per cent.

Mr. F. C. Carpenter, county surveyor of the West Riding of Yorkshire, stated at the First International Road Congress at Paris in 1908, that the average cost of maintenance of the roads in his district in 1890 was $482 per mile, but at that time had increased to $798, reaching in some cases as high as $3,900, while in others it was as low as $73. On the average it was $1,120 for urban roads and $584 for rural roads. He attributed the greatly increased cost in later years to the use of the roads by motor vehicles.

These conditions have been generally recognized elsewhere, both at home and abroad. The Route Nationales in France, reputed to be the finest roads in the world, especially those built of the softer limestones in southern France, have been so destroyed by motors that their maintenance, at any reasonable cost, as water-bound roads have become almost impossible.

These facts are sufficient to show the damage that motor vehicles are doing to our roads of the water-bound type, but it must be remembered that if the traffic consisting of horse-drawn vehicles had in itself increased to the same extent as the number of motor cars now using our roads, the cost of maintenance would have increased to a large extent. Before 1900 there was no demand for trunk line roads to be used by horse-drawn vehicles in the same way that they are now used by motors.

The number of self-propelled vehicles is increasing every year. Mr. Maybury, county surveyor of Kent, England, states that the increase in England in the year ending December 31, 1910, was no less than 36,935 and that this is more than likely to be maintained. In New York State more than 81,000 were licensed in 1910, in Massachusetts over 35,000. In the latter state more than one third of its vehicles are motor driven. On some of the roads near Boston automobiles furnish more than sixty per cent. of the traffic, and, during the summer, ninety per cent. of the vehicles used on the leading state roads

were of the motor car variety. The conditions in both countries are seen to be the same. Lord Montagu, of Beaulieu, has calculated that the amount of gasoline used in motors in England in the year 1910 was sufficient, at 15 miles travel per gallon to represent a mileage of 600,-000,000, and Mr. Maybury says: "What are we engineers doing to meet this revolution in traffic?"

The very general answer to Mr. Maybury's question is that some form of bituminous binder must be used, either in or on the surface of the road to enable it to resist the destructive action of the motor vehicle. This was the conclusion reached at the two International Road Congresses held in 1908 and 1910. The water-bound broken-stone road is a thing of the past on our main arteries of travel which are carrying the present enormous motor traffic.

In working out the problem of a new type of road construction in which some form of bitumen is employed as a binding or surfacing material science can, and is, taking an important part. Fortunately for the past twenty-five years or more, the native solid bitumens, the liquid forms and their surrogates, the tars, have been studied very thoroughly as to their character and in their application to the construction of street pavements. It is not, therefore, difficult, for one who has had an extended experience, to apply the knowledge gained thereby to the construction with the same materials, of country highways of broken stone. The contribution which science has offered to the solution of the road problem in this direction is, therefore, important, while it supplies at the same time means of controlling the uniformity of the binding materials in use and determining the fact that any particular bitumen is of suitable character for the purpose to which it is to be applied. For the collection of these data and also, to a great extent, for their interpretation the highway engineer is dependent on the chemist, who is, therefore, becoming a considerable factor in successful road building.

Bitumen is a native material, that is to say, it is found in nature. The by-products of industrial operations, such as tar from the manufacture of illuminating gas and coke ovens, is not bitumen in the acceptation of the word as it was originally applied by the Latin writers. Coal tar is a bituminous substance merely from its resemblance to bitumen.

Bitumen is a mixture of hydrocarbons and their derivatives and may be gaseous, liquid, a very viscous liquid, sometimes called a maltha, or a solid. These hydrocarbons may be representatives of very different series, each having its own peculiar character, both chemical and physical, or a bitumen may be made up of hydrocarbons of different series. The value of any bitumen or combination of bitumens for road construction depends on the series of hydrocarbons and their derivatives,

more particularly the sulphur compounds, of which it is composed. The consistency of such material and its suitability in this regard for use as a road binder is further dependent on the relative proportions of liquid and solid bitumens of which it is composed. It is, of course, the province of the chemist to determine these characteristics for all bitumens proposed for use in road construction, and to interpret the result in the light of practical experience.

From the point of view of their solubility or insolubility in petroleum naphtha the liquid and solid bitumens in use in bituminous highway construction are composed of two components, one of which has been arbitrarily named as a class petrolenes, soluble in naphtha, and the other, asphaltenes, insoluble in naphtha. The one consists of the liquid and the other of the solid components. Whatever value a bitumen may have as a binding material for highway construction, is due to the presence and the character of the petrolenes. The solid material in itself has no binding power, but by its solution in or mixture with the petrolenes it gives to the latter their binding power, and also adds to their stability.

The value of a bitumen as a road binder will further depend upon the character of the petrolenes which it contains. If the petrolenes are of a sticky nature, the particular bitumen will be adhesive and cementitious, whereas if they are merely oily and not sticky, the material will lack in cementitious properties. The asphaltenes impart cohesiveness as distinguished from adhesiveness, and supply body or stability, as has been said, to the binding material. As an example it may be cited that the heavy residuum left on the distillation of paraffine petroleums in the preparation of burning and lubricating oils, consists of practically 100 per cent. petrolenes, but these petrolenes are oily and not sticky and adhesive. The same is true of any of the preparations from paraffine petroleums or petroleums containing a considerable amount of hydrocarbons of the paraffine series. It is not in itself a suitable binding material for highway construction as appears, not only for the reasons given, but by its behavior in actual use. The petroleums derived from the asphaltic oils, on the contrary, such as those of Trinidad, California and Mexico, are of a much more sticky character, and are not only in themselves, when reduced to a proper consistency, more suitable for a binding material, but are particularly desirable when used to soften solid and harder bitumens, known as asphalts, which possess great cohesiveness, but are wanting in cementing properties. The relative proportions of sticky petrolenes and cohesive asphaltenes is the most important element in bitumens which are used in the construction of asphalt pavements and bituminous highways. It has been found that the asphalt cement, that is to say, a solid asphalt combined with a suitable flux to provide the proper consistency for practical use, if it

contains less than 15 per cent. of asphaltenes will lack cohesiveness and stability or body, while, on the other hand, if it contains less than 70 per cent. of petroleum it will not be sufficiently adhesive. Even with the proper proportion of petrolenes and asphaltenes a bitumen may still be valueless as a cement, if the petrolenes are not of a proper character, that is to say, not sticky. These are all facts to be determined by the chemist, and his contributions to the subject have been of the greatest importance to the development of bituminous highway construction. The characteristics which he determines may be summarized as follows:

1. *General Characteristics.*—The series of hydrocarbons of which the bitumen is composed for the purpose of comparing it with those in standard materials.

2. *Purity.*—The amount of bitumen apart from the mineral or other matter, with which it may be contaminated, to regulate the amount of it which should be used under various conditions.

3. *Adhesiveness.*—Arrived at from a determination of the specific gravity of the bitumen, its solubility in naphtha, the amount of paraffine scale which it contains, this being evidence of the facts that paraffine petroleums are present in the material or absent, and its ductility or extent to which a small test piece can be elongated under tension without fracture.

4. *Cohesiveness.*—Determined by the percentage of asphaltenes which the material contains, and by the residual coke remaining after ignition of the material in absence of air, which bears a close relation to the percentages of asphaltenes present.

5. *Consistency.*—Determined by the depth to which a weighted needle will penetrate into the material, under a definite weight, at a definite temperature, during a definite period of time.

6. *Viscosity.*—Determined by the rate at which the material will flow through an aperture of definite size, at a definite temperature, in a definite period of time.

7. *Capacity to Resist Temperature at Which it Becomes Sufficiently Liquid to be Used in Actual Construction.*—Determined by the volatilization of the material when exposed for a definite length of time in a definite amount, to the high temperature at which the materials would be used.

8. *Safety.*—Determined by the temperature at which the vapor arising from the material at high temperatures, such as those used in manipulating it, will flash or take fire.

Determination by the chemist of the above characteristics and comparison of them with well-known standards enables him to say whether the bitumen in hand possesses those which have been recognized as desirable in similar materials which have been subjected to service tests in actual work with successful results.

The methods of making the above determinations have been elaborated during the last twenty-five years to such an extent that they may be relied on for the purpose for which they are used, although they will, no doubt, be improved in the future, as they have been, from time to time, in the past. At present they are sufficient, not only as furnishing data which will form a satisfactory basis for arriving at the character of any bituminous material, but also as a means for control of the uniformity of any supply which may be selected, and for regulating its use in actual highway construction.

From what has been said it can be seen that the rôle of the chemist in highway construction to-day, where bituminous materials are becoming so important an element of it, is an important one, that science can contribute much to the improvement of highway construction, and that these contributions should not be neglected where it is proposed to do the highest type of work, and to produce a highway surface which shall resist the heavy travel to which they have been subjected since the advent of the motor car.

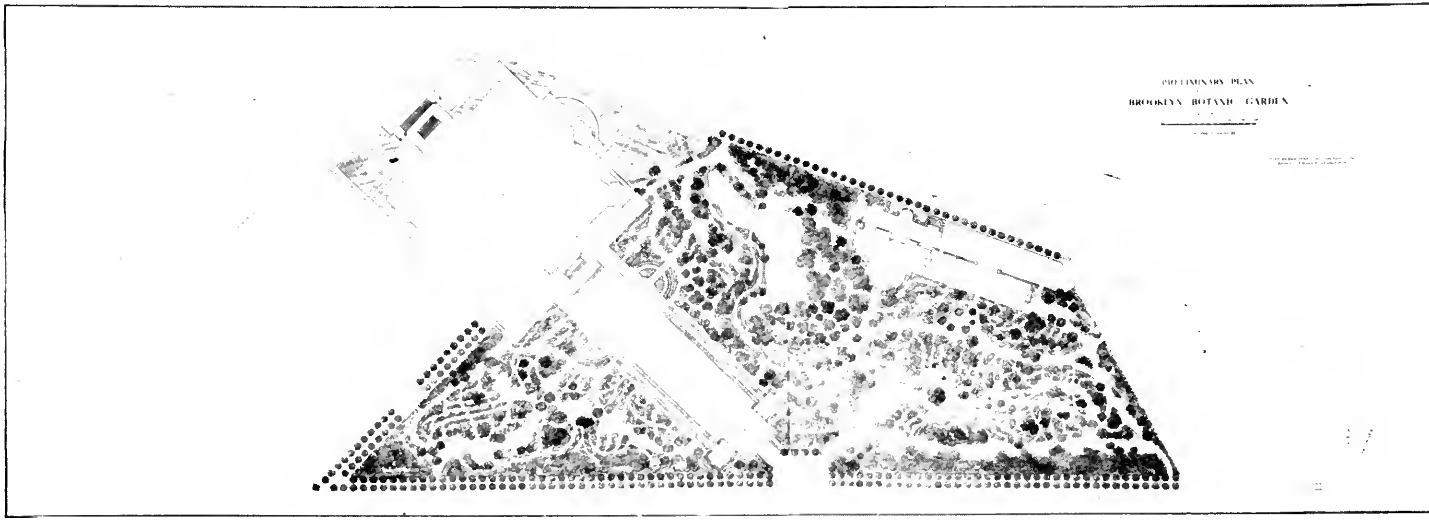


FIG. 1. BROOKLYN BOTANIC GARDEN. Preliminary plan of the grounds.

THE BROOKLYN BOTANIC GARDEN

By Dr. C. STUART GAGER

BROOKLYN BOTANIC GARDEN

THE Brooklyn Botanic Garden is a department of The Brooklyn Institute of Arts and Sciences. The institute itself, an organization of some 7,500 members, is the outgrowth of a movement starting in 1823, for the establishment in Brooklyn of a free library for apprentices. From these small beginnings, the work has gradually expanded, until now it is carried on by means of twenty-eight departments, representing various branches of art and science, and including courses of lectures and general university-extension work. During 1893–94 the establishment of a museum of arts and sciences was undertaken, and this movement has steadily developed, until now there is a large Central Museum on Eastern Parkway, beautifully housed in a building only partly completed, and in Bedford Park a wholly unique branch, the Children's Museum, described in The Popular Science Monthly for April, 1908.

The Botanic Garden movement found its first public expression in 1897, when the Hon. George W. Brush, M.D., introduced into the state legislature of New York a bill providing for the establishment and maintenance of a botanic garden and arboretum on park lands in the city of Brooklyn. The bill, which became a law on May 18, 1897, names among other objects of the garden, the advancement of botanical science and knowledge, and the prosecution of original research therein

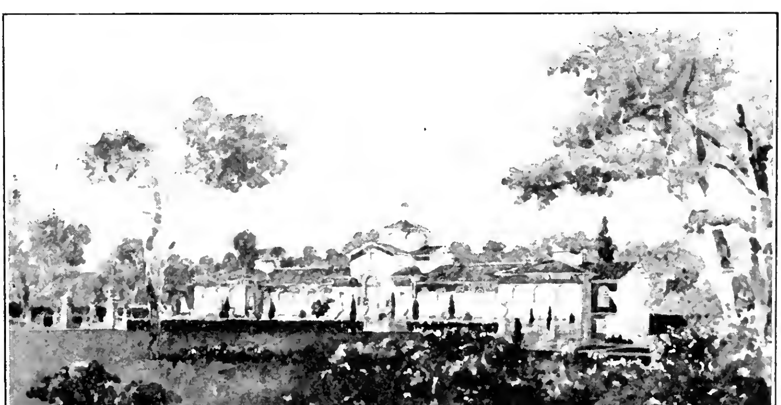


Fig. 2. Laboratory and Administration Building. Front (west) elevation, facing the Garden.

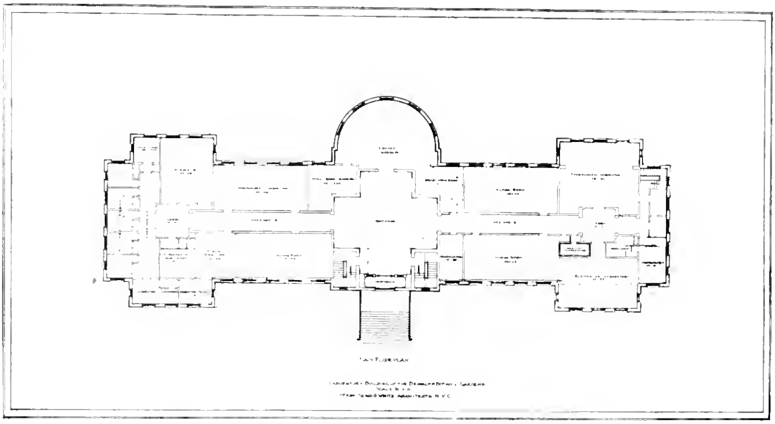


FIG. 3. LABORATORY AND ADMINISTRATION BUILDING. Main floor plan.

and in kindred subjects, the giving of instruction in the same, and the maintenance of public exhibits of a botanical nature.

The assignment of the necessary lands by the city was made contingent on the institute providing a private fund of at least $50,000. Public-spirited citizens of Brooklyn, who wish to remain anonymous, offered, in June, 1905, to give $25,000 toward this fund, and in December, 1906, this offer was doubled, thus completing the $50,000 required.

The garden grounds, turned over to the institute by the city on February 1, 1911, comprise approximately forty-three acres, lying to the south and west of the Central Museum building, in the very heart of the borough of Brooklyn. The plan of the garden, as laid out by the landscape architects, is shown in Fig. 1. The main entrance, on Flat-

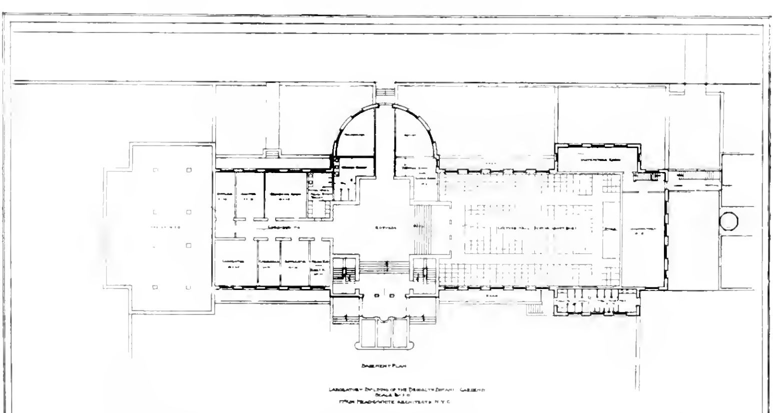


FIG. 4. LABORATORY AND ADMINISTRATION BUILDING. Plan of the basement. In the final plans the northeast "Instructors' Room" has been divided into three smaller rooms.

bush Avenue, opens northward through an esplanade to the museum building, and southward and eastward to the public conservatories and the laboratory and administration building. In the northeast corner of the garden is a lake of about three acres in area, and the adopted plans provide for a small stream leading southward through the grounds from the lake. The lake and stream together will afford excellent opportunity for aquatic planting.

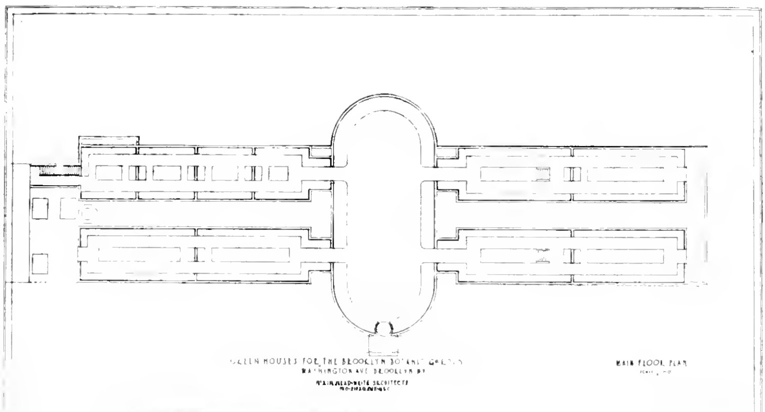


FIG. 5. CONSERVATORIES OF THE BROOKLYN BOTANIC GARDEN. Main floor plan. The northeast house (at the left) connects with the Physiological Laboratory. The division of the northeast wing into four houses is made with reference to their use for class work and for investigations.

The location of the garden is of considerable physiographic interest, for it is situated on the extreme southern margin of the terminal moraine deposited by the continental ice-sheet. As is well known, a portion of this moraine forms the so-called "backbone" of Long Island, and two or three morainal knolls give relief to the northwestern and the eastern edges of the grounds. The remainder of the garden is on the area of the overwash plain lying south of the moraine, but the surface soil is no longer of geological significance in this connection, as there have been considerable grading and top-soiling in connection with park operations. A few large glacial boulders remain in place and exposed at the surface.

The laboratory building, when completed, will be a one-story and basement structure of brick, faced with concrete, about 240 feet long, and 50 feet wide, with a maximum elevation of about 60 feet (Fig. 2). At suitable places on the exterior will be placed the names of noted botanists of the past. For this purpose there are twenty-two spaces on the frieze for names of greatest prominence, each space to contain only one name. Under each window is a panel to contain three names. The choice of names was determined by a vote of contemporary American botanists.

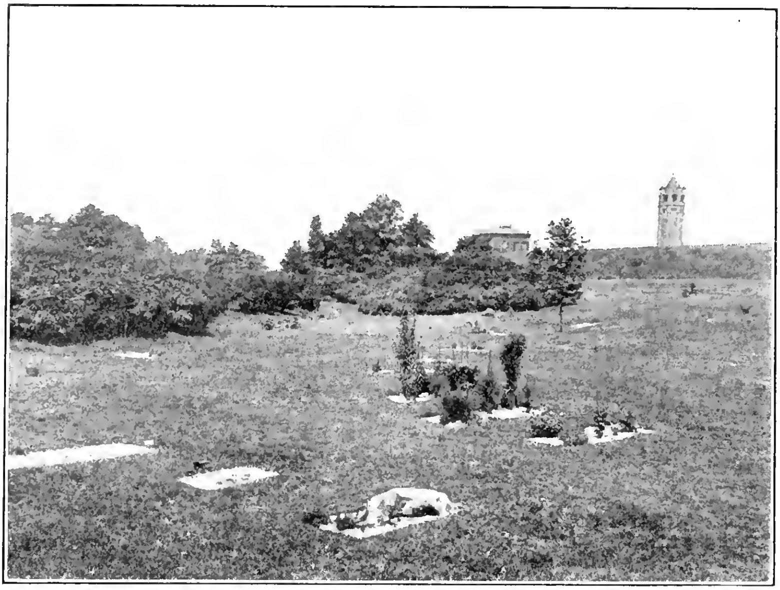


FIG. 6. NATIVE WILD FLOWER GARDEN (LOCAL FLORA SECTION) OF THE BROOKLYN BOTANIC GARDEN, AUGUST 14, 1911. A small portion of the bog shows at the extreme left. The slope at the right is now thickly planted with local flora shrubs. In the background is shown the Prospect Heights reservoir, with water tower, and the laboratory of the municipal Department of Water Supply, Gas and Electricity.

The main entrance to the laboratory building from the west or garden side opens into a central rotunda (Fig. 3). East of the rotunda is the well-lighted main library room, with an area of 1,050 square feet. Opening from this at one side is a stack room with a capacity for 10,000 volumes; at the opposite side, a librarian's work room, part of which may also be used for stacks. There is additional shelving space in the main reading room.

The portion of the building north of the central pavilion contains the public and private offices and the private laboratory of the director; a morphological laboratory 20 × 40 ft.; a herbarium room 22 × 28 ft.; a class room 20 × 40 ft.; six private research rooms 9 × 12 and 11 × 12 ft., and an experimental dark room 12 × 15 ft.

The southern wing contains two class rooms, each 20 × 40 ft.; an instructors' room 10 × 20 ft.; an elementary laboratory 23 × 34 ft.; a physiological laboratory 28 × 34 ft.; a constant-temperature room; a photographic operating room with overhead light, connecting with a photographic dark room, and two private offices for members of staff. The physiological laboratory connects with one of the wings of the conservatories, reserved for experimental work. Passage from one to the other may be had without going out of doors.

In the basement (Fig. 4) is a lecture hall with a seating capacity of about 500. At the south end are three private rooms for members of staff, and a well-lighted laboratory 18 × 37 ft. The remainder of the basement is occupied by service rooms, as shown in Fig. 4. Under the south end of the building is also a sub-basement, containing four rooms.

The conservatories (Fig. 5) consist of a central palm house 104 feet long and 45 feet wide, with two south wings and two north ones. The greatest height of the palm house is 36 feet. The south wings are each divided into two houses, each 50 × 22.5 ft., and from one of these, stairs lead down to a "mushroom" cellar. The northwest wing is like the south ones, but the northeast wing is divided into four rooms, each 25 × 22.5 ft. These rooms are reserved primarily for class use and for investigators. In the basement under the south wings are stables, a potting room, gardener's office and other service rooms.

During the spring and summer of 1911, the installation of the plantations was begun. The Local Flora Section or "native wild flower garden" (Fig. 6) was laid out and partly planted. In this section is an artificial bog (Fig. 7). The Morphological Section was also started, subdivided into a Division of External Anatomy, and a Division of Comparative Morphology. The third section planted was the Economic Garden (Fig. 8), which is of especial interest in a large city,

FIG. 7. BROOKLYN BOTANIC GARDEN. A corner of the Local Flora Section, showing the artificial bog. The large label near the center of the picture locates and describes the insectivorous plants. The labels under the edge of the shrubs designate shade-loving sorts. August 14, 1911.

where many of the visitors, especially among the children, have never seen the common food-plants outside of a grocery store, and have never seen any of the fiber and medicinal plants at all.

Aside from the labeled plantations, which in reality constitute an out-of-doors museum, and the conservatory collection, no museum will be developed in connection with the garden. The close proximity of the Central Museum building of The Brooklyn Institute of Arts and Sciences makes a separate static exhibit by the garden unnecessary, for the plans of the museum include an extensive botanical section.

On account of the ample facilities already offered in Greater New

Fig. 8. Economic Section of the Brooklyn Botanic Garden. The first two rows of beds contain food and fodder plants; the third row, medicinal plants; the fourth row, condiments and relishes; the fifth row, fiber plants. August 14, 1911.

York for work in systematic botany, no attempt will be made to develop a systematic center at the Brooklyn Garden. Only such a herbarium will be assembled as represents the local flora, as the needs of other departments indicate, and as the proper naming and labeling of the collections makes necessary. Investigations will be confined to other subdivisions of the science than taxonomy, such as physiology, pathology, morphology, experimental evolution and phases of economic botany.

Annual city appropriations for the maintenance of such an institution as a botanic garden are, of course, justified only by the service which the garden can render to the city. In this connection it may be stated that it was the wish of those instrumental in securing the estab-

lishment of the garden that the formal teaching of botany to classes be emphasized here to a greater extent than has hitherto been customary in botanic gardens; and especially that the garden articulate in every feasible way with the botanical work of the elementary and advanced schools of the city, both public and private. Lectures and courses of lectures and laboratory courses will be offered to pupils in the city schools; to a limited extent material for class study will be provided, a system of docentry will be developed, and courses for teachers will be offered. Thus, and by means of its library, laboratories and labeled collections, indoors and out, and by its encouragement and ample provision for research, will the garden endeavor to realize its ideal of "the advancement of botany and the service of the city."

ALEXANDER VON HUMBOLDT[1]

By Dr. EDWARD F. WILLIAMS
CHICAGO, ILL.

WITH Baron von Humboldt, says the late Professor Louis Agassiz, "ends a great period in the history of science: a period to which Cuvier, Laplace, Arago, Gay-Lussac, De Candolle and Robert Brown belonged." It was a period of tireless research, of important discoveries, of brilliant generalizations. It was a period in which the specialist appeared, and secured for himself an honorable position. Yet there were men, and among them Humboldt the most distinguished of them all, who were deeply interested in all departments of science, men who sought to master at least their elementary principles and to render themselves able to judge intelligently concerning the conclusions which were reached. Since Humboldt passed away it is doubtful if any one has lived who in the extent and accuracy of his knowledge, the breadth of his vision and the soundness of his judgment can be compared with him as an equal. All the more true is it that his death in 1859 closed an era in the scientific world.

It was in this year that Charles Darwin published "The Origin of Species" and that the Fraunhofer lines of the spectrum were discovered. The theory of evolution was the outcome of studies which Darwin's book compelled the scientific world to undertake. With the full, or even partial, acceptance of that theory new methods of study have been introduced into nearly every department of learning. In the face of such a theory it has been impossible to be satisfied with the old views of history, literature, philosophy, theology, to say nothing of science. It is therefore a matter of no little interest to know what were the views of Humboldt and his co-laborers during the period above mentioned, upon which the foundation of a new era was built. For a clear and accurate statement of the scientific knowledge of his time no work is more worthy of confidence than Humboldt's "Cosmos", of which Vol. I. was published in 1845, Vol. II. in 1847, Vol. III. in 1850, Vol. IV. in 1858 and Vol. V. soon after the author's death. The earlier editions were constantly improved, and the entire edition, furnished with notes, containing extracts from private letters or publications of distinguished men which are of great interest and value, has appeared again and again. Admitting, as we must admit, that many, perhaps most of the conclusions reached in this work, have been set aside by later discoveries, the

[1] "Cosmos," Vols. I.–V., Harper & Brothers, New York.

material gathered and arranged in Volumes I. and II. will always be worthy of consideration and the methods employed in securing it will never fail to be suggestive and useful. That his opinions would require modification, and that some of them might be rejected altogether, is what Humboldt himself anticipated. He calls attention repeatedly to the fact that he and his fellow students were on the threshold of discoveries which might change the entire scientific outlook and furnish even the next generation with an immense advantage over his own.

Friedrich Heinrich Alexander von Humboldt was born at Tegel, near Berlin, on September 14, 1769. He died in Potsdam, where his house is still shown to visitors from every civilized country, on May 6, 1859. His elder brother, William, was distinguished as a statesman, diplomatist and linguist. As the founder, while minister of public instruction of the University of Berlin, he made a great contribution to the intellectual development of the German people. The father was a major in the Prussian army and had been chamberlain at the court of the king. The mother, Marie Elizabeth von Colamb, the widow of Baron von Hollande, was a woman of rare gifts. She devoted herself almost entirely to the training of her two sons, her only children, William and Alexander. As the father died when Alexander was but ten years old, the responsibility of their education fell upon her. Fortunately the family was wealthy, so that private teachers could be provided for the boys at Tegel, among them men like J. H. Camp, famous for his ability to impart knowledge; Christian Kunth, eminent in the educational world, and T. T. Engel. From Tegel the boys were sent to Berlin and put under the care of specialists, whence they were removed to the University of Frankfort on the Oder, thence to Göttingen, where Alexander studied philology and archeology under Heyne, and gave special attention to the philosophy of Kant. His natural love for science was deepened and strengthened by his association with Professor Blumenbach, one of the great men of the university. Destined for business, young Humboldt went from Göttingen to Hamburg and entered the commercial school of Bursch, where he studied modern languages with much zest and listened to lectures on banking and trade. But he soon found that his love for science was greater than his love for money-making, and for this reason, without wholly giving up the thought of a business career, he left Hamburg for the mining school at Freiburg, where he enjoyed the instruction of Werner, the geologist, of the equally famous Leopold de Buch and of Andre del Rio. In a single year he made such progress that in 1792 he was appointed director general of the mines in the district of Franconia and Aspach, with headquarters at Bayreuth. In this position he remained five years, but while faithfully discharging the duties of his official life he found time for brief visits to the Tyrol, Switzerland and Lombardy for the study of botany and geology. With George Foster, a friend of his student years,

and the person to whom, as he often declares, he owed his first impulse to the life he led later, he had previously visited England, Holland and Belgium. It was this George Foster, the companion of Captain Cook on his second voyage round the world, who suggested to Humboldt his travels and researches in the tropical world.

As an author young Humboldt had already given proof of far more than ordinary ability. At Göttingen he had written a book on the "Basalts of the Rhine," and in 1792 published a striking essay on the "Fossil Flora of Freiburg." While inspector of mines, employing the discoveries of Galvani, he published two volumes, still frequently consulted, bearing the title, "Über die gereiste Muskel- und Nervenfassen nebst Vermuthengen über den chemischen Process des Lebens in der Thier- und Pflanzenwelt," Berlin, 1797.

The death of his mother, to whom he was warmly attached, and the increase of his income made it possible for him to carry out long-cherished plans for travel and the study of nature in the tropics. Resigning his position as inspector of mines, he visited Vienna and Paris for special studies and for the purchase of instruments and instruction in their use. In Paris he met Gay-Lussac, Laplace, Arago, Berthollet, and Aimé Bonpland, a young botanist who became his companion in travel and research, and in whom he found the friend and assistant whom he needed. Failing in their attempts to make satisfactory arrangements for explorations in Egypt and Central Africa, the two men finally accepted the protection and assistance of Spain, and decided to devote themselves to the study of the physiognomy, the plant and animal life of the tropical regions of South and Central America and Mexico. At the head of an expedition which in equipment and retinue had hardly been equalled since the days of Alexander the Great the two men sailed from La Coruña in northwestern Spain, June 5, 1799, and landed at Bordeaux, France, on their return home, June 3, 1804. During their absence they had explored Venezuela, ascended the Orinoco 1,800 miles and learned that its head waters are connected with those of the Amazon, had sailed up the Magdalena, settled for a time at Quito and made themselves thoroughly acquainted with the west coast of South America almost to the southern limits of Peru. They had ascended Chimborazo to the height of 19,000 feet, had studied carefully the crater of Cotopaxi and learned all that could be learned at the time concerning the physiognomy of the country. They had studied the forms of life, animal and floral, observed the variations of temperature at different levels above the sea, the arrangements of the mountain chains, the situation and character of volcanoes, active and extinct. They had studied under favorable conditions the celestial phenomena peculiar to the tropical regions and given special attention to the zodiacal light. From the people and their own observation, they had learned all they could learn concerning the country, its civilization and

history, its institutions of culture and religion, its resources, agricultural and pastoral, its mines, its timber and its capacity under more favorable conditions to contribute to the sum of human happiness. They had made use of the discoveries of previous visitors, like Condamine and Bourguer of the Academy of Sciences in Paris, who were in the country from 1742 to 1747, and by their observations had made it easier for future explorers, like Boussingault, who followed them twenty-three years later, to profit by their stay in the country. Incidentally Humboldt learned the value of quinine as a medicine, and is to be credited, in part at least, with having made it known in Europe. He and his companions ascertained the location of places by astronomical methods, noted accurately the movements of the barometer so important in determining the character of the climate, and did not overlook at all the botany, the mineralogy, the geology, or even the archeology of the country. Having completed their observations in South America and made a vast collection of specimens of various sorts, which they sent to Paris, they sailed in 1803 for Acapulco, Mexico, where in studies of that country and of Central America they spent nearly a year. Only a few weeks were given to the United States, whence they sailed directly to Bordeaux, France.

Having reported to the King of Prussia and passed nearly two years in and around Berlin, Humboldt obtained leave to visit Paris and arrange for the publication of the results of his explorations. The work which he had thought would occupy him possibly three or four years extended to twenty and even then was unfinished. In Paris, of which he was extremely fond, he associated himself with some of the ablest living scientists of France and with their assistance gave to the world, during the years 1807–1827, thirty volumes of description and discovery. If the scientific world was astonished at the contents of these volumes and the regularity with which they appeared, it soon found that the knowledge for which Humboldt made himself responsible was as accurate as it was extensive. Many of these volumes, in which more than two thousand very costly illustrations appeared, were written by Humboldt's associates, but no one of them left the press without his oversight and approval. It is little wonder that his name was in high repute in every part of the civilized world, that he was chosen a member of nearly every learned society in Europe, or that by general consent he was accounted the first scientific man of the age. This reputation, so early acquired, he retained till his death. Nor were his honors derived from the scientific world alone. While living in Paris he was often employed by his king as a diplomat, and with great profit, for he was a favorite at the court and in the best social circles of the city. A little above medium height, with regular features, beaming eyes, a rare charm of manner, and with a capacity for friendship rarely equalled (it is said

he never lost a friend) he was almost as famous for his social as for his scientific victories. Yet he never married.

It was with real sorrow that he obeyed the command of his king and left his dearly loved Paris to pass the remainder of his life in Potsdam. He was in the fifty-ninth year of his age, in perfect health and deeply interested in every department of learning as well as in those special fields to which he had given personal attention. A home was provided for him at Potsdam, a liberal salary paid him regularly, so that, barring the demands which the king made upon him for diplomatic services (and these were not infrequent), as a companion of his official visits, or as a visitor at the palace, he was free to pursue his studies. The German public, proud of his renown, rejoiced in his return to his native land and read with increasing interest and enthusiasm whatever came from his pen.

His lectures at Berlin in the winter of 1827 and 1828, which formed the basis of "Cosmos," were heard with astonishment and delight.

A man like Humboldt, so widely known and so thoroughly trained as an explorer and observer, could not long be permitted to remain quiet in any one place. At the request of the Czar of Russia, under his protection and at his expense, with Ehrenberg, the microscopist, Gustav Rose, the chemist, and Menscherlisch, an engineer, he made a rapid but intelligent survey of Asiatic Russia, giving particular attention to the Ural and Aral Mountain chains. It was on this journey that diamonds were discovered in the Ural Mountains and secured to the government for its control and profit. Ehrenberg and Rose published separate accounts of this journey and Humboldt's "Central Asia" is an enlargement and revision of his first report, which appeared simply as a fragment, on the geology and mineralogy of the country.

While in Paris he had experimented with Gay-Lussac on the nature and qualities of gas, and with him as a companion had visited Rome, where his brother William was the Prussian minister, in order to study magnetism. It would take a good-sized volume to give an account of the various services he rendered the king, and of the journeys he made as a diplomat, nearly always with success, and in the interest of science. He was in the seventy-sixth year of his age when he made public his intention of writing that great work of his life known as "Cosmos." Previous treatises he looked upon as preliminary sketches compared with the work he would now compose and in which he would try to give an accurate and sufficiently full account of all existing scientific knowledge. In this work, while presenting general rather than detailed conclusions or statements, he would show that nature, in spite of her seeming complexity, is yet a unit and governed by a definite and well-ordered plan. A master of the materials furnished by the most eminent scientists of the day, without claiming for himself to be an authority in any single department of science, he believed himself better fitted by reason of

his acquirements, his acquaintance with the scientific men of every country, his wealth, his relation to the king, his leisure, than any other living man to write the book he proposed. He had the promise of assistance from the representatives of all the sciences, and through private correspondence and their publications could obtain from them the latest and most accurate information on the topics he wished to discuss. It is not strange that one of the striking features of "Cosmos" should be its notes, which contain extracts in many cases from private letters and from publications in journals rarely seen, by men whose names Humboldt seems to take pleasure in mentioning, and to whom he never fails to give full credit.

Yet, modest as he is in reference to his own acquirements, he may justly be regarded the founder of the sciences of meteorology, terrestrial magnetism and the physics of the sea. To him more than to any man of his time is due the interest in the study of the currents of the air. It was at his suggestion and after his plans that the Russian government established, from one end of its dominions to the other, stations for the observation and record of magnetic phenomena. It was through his influence that England did the same in her territories, and that other countries have to a certain extent followed these examples. Perhaps it may be added that he is the founder of the science of geodesy. At any rate he was the first to give a full and complete picture of the physical features of the earth and to call attention to the effect of these features and of the temperature of a country upon its inhabitants. The tracing of isothermal lines is due to him. In fact, during his life few new steps were taken or changes made in scientific study without suggestions from him or consultations with him. One of his characteristics was his fondness for young men, and the pleasure he took in aiding them. If he was a little vain, apparently somewhat self conscious, it was by no means unnatural. The friend of kings, a social lion, a successful diplomat, a classical scholar of nearly the first rank, well versed in history, ancient, medieval and modern, at home in modern languages, a master of the best literature of the century, through his brother William, well-acquainted with oriental literature and with the conclusions of the comparative study of language, the pride of the German people, recognized on all sides as worthy of the highest honor a man can receive from any source whatever, it would be contrary to nature not to be influenced to some extent by the flattery which came from every side. Without an exception the scholars of Europe recognized his greatness and his eminent fitness for the work he proposed to undertake. The work had been on his mind for at least twenty years. For it he had gathered material, had pursued special studies, made special visits, cultivated the friendship of eminent men, by constant thought formed the plan which he finally carried out, of presenting in clear readable form an account of all that had been discovered and accepted as worthy of belief in the scien-

tific world. As we think of this aged but vigorous man sitting down in his study in Potsdam with the learning of the world at his command, with every literary or scientific man in Germany or France or Italy or Russia ready to furnish any information he might ask, we can not help sympathizing with him in his conviction that he was indeed the best man living to write a book like "Cosmos." The reports published in Paris had, in his eyes, only prepared the way for the generalizations he would now make. Yet to the ordinary man they seemed complete in themselves. They covered a vast field of exploration and study. They had engaged the labors of some of the most eminent men in their departments for twenty years. These reports, arranged in six sections filled thirty volumes. These sections are as follows, viz.,

I. Historical, Geographical and Physical Atlas; Views of the Cordilleras and of the Native Peoples of America.

II. Observations on Comparative Anatomy and Zoology.

III. Political Essay on the Kingdom of New Spain.

IV. Astronomical Observations; Trigometrical and Barometrical Measurements.

V. Essay on Geological Basiography.

VI. Equatorial Plants.

In the International Encyclopedia it is asserted that Vols. I.–XIV. were written by C. S. Kunth, the botanist. They treat of botany almost exclusively. On the South American journey hundreds of new species of plants were discovered and described, and specimens of them sent to Paris. The general title of this extensive work was "Voyage aux regions equinoxiales du Noveau Continent fait en 1799 . . . 1804 par Alexandre de Humboldt et Aimé Bonpland." Volumes XV. and XVI. are an "atlas pittoresque."

With the exception of Volume XX. which is devoted to plants, Volumes XVII.–XXII. are occupied with physical geography, geognosy and astronomy. Volumes XXIII. and XXIV. are given to zoology, and Volumes XXV. and XXVI. to a description of the countries of Spanish America. Volumes XXVII. to XXX. contain Humboldt's own narrative and notes upon the countries visited. Unfortunately this narrative was never quite finished. The original work contained the "Essai politique sur royaume de la Noveau Espagñol," the "Essai politique sur l'isle de Cuba," and "Vues des Cordilleries." Special sections of this immense work appeared from time to time under individual titles, and as composed by specialists of distinction. Humboldt's "Ansichten der Natur" was very popular in Germany, as was an edition of his works published in 1864–1866. In Bruhn's "Life of Humboldt," it is shown that he made special contributions to petrography, vulcanology and seismology, that he pointed out the effect upon civilization of the cultivation of the soil in different climates, and drew attention to the languages, architecture and customs of the ancient peoples

of South and Central America and Mexico. He was the first, so it is claimed, to mark the decrease in intensity of magnetic force from the poles to the equator. At any rate, his journey to the tropical possessions of Spain in the new world gave a very decided impulse to the study of natural history.

It is not strange that a man with his extensive knowledge, his varied experience as a traveler and the resources of the scientific and literary world at his disposal should desire to write and publish a work that should set forth in clear and accurate form all that in his time was known of the earth and the celestial bodies. If any man was ever justified in the belief that he could satisfy his ambition in this respect it was Alexander von Humboldt at the age of seventy-six.

"Cosmos" is a history in outline of the physical contemplation of the universe. Its aim is to show the unity of the universe. It is not a history of the natural sciences as such, rather an attempt to point out the close connection of all the forces of nature. To do this all possible sources of information are laid under tribute. In his study of what has been done and is now known, Humboldt pledges himself to follow three laws, or to be guided in his thought and writing, by three principles: viz.,

1. To show the efforts of reason, through meditation upon phenomena to obtain a correct knowledge of natural laws.

2. To consider events which have suddenly enlarged the horizon of observation.

3. To show what has been the result in the enlargement of the fields of human knowledge through the discovery of new means of sensuous perception, or of new organs, or instruments by means of which we are brought into closer touch with terrestrial and celestial objects. Thus in the telescope and the microscope we have new organs of perception.

Starting from the basin of the Mediterranean, with its three contiguous closed seas and its three peninsulas, Spain, Italy and Greece, the discoveries made by voyages to other countries are named, and the fact stated that the earliest civilizations were developed in countries rich in rivers, as Egypt, Messopotamia, India and China. The author takes pains to emphasize the exceptional men who lead in new movements in travel, who make startling and important discoveries. Nor does he overlook the events which mark the beginning of new eras in the world's history. He has the rare faculty of making us see how striking contemporaneous events often are. For example, when Columbus discovered America, Copernicus was studying astronomy with Brudzewski in the University of Cracow. The rapid extension of knowledge at the beginning of the seventeenth century was due to the studies and discoveries of Galileo and Kepler, at its close to those of Newton and Leibnitz. It was in this century that the problems of

light, heat, magnetism, double refraction and the polarization of light were partially solved. Some traces of a knowledge of the results of the interference of light are seen in the works of Grimaldi, Hooke, William Gilbert and Halley. But it was the discovery of the calculus by Newton and Leibnitz, and its use by scientific men, that the new impulse was given to the study of astronomy and physics. Some of the marked periods in history may be mentioned. One of these periods was that of the Argonautic Expedition under Jason in search of the Golden Fleece which took place about 1200 B.C. Another was the passage of Europeans into the regions of the Euxine and the settlements made there by the Greeks; another the expeditions of Alexander the Great, whose campaigns have been called scientific as well as military. Another period of great importance is marked by the growth of scientific interest, especially in Egypt, under the Ptolemies, and still another by the dominion of Rome and the influence of the Cæsars. In the Middle Ages, Arabs who had absorbed and added to the learning of the Greeks, brought it back from Bactria, a kingdom which lasted 116 years, to western Europe and thus in the fifteenth century became the pioneers in the new world of awakened thought. Phœnicians led in the early voyages of explorations. The Greeks followed and established colonies on the coasts of Asia Minor and on the southern shores of the Black Sea. Wherever Romans went they remained as conquerors. From the Phœnicians we have few descriptions of nature. From Roman writers like Cicero, Ovid, Livy, Cæsar, there are more. There are some also in the writings of the Greeks from Homer and Hesiod down, but for the most part the interest centers in man, not in the beauty or striking features of the region in which he lives. The Hebrews are not insensible to the importance of natural scenery upon the character of men, nor are they unable to give vivid utterance to the impression which sublime scenery, as witness Ps. 104, makes upon them. From the christian fathers, as in the writings of Basil the Great, whom Humboldt especially admired, we have many descriptions, though even here the human element is always of prime importance. The Aryan races, natives of India and Persia, recognize the charms of nature, but still *men* are the objects upon which interest in their writing rests. In the early Italian writers, and in the poets to the time of Petrarch and Dante, there is evidence of a growing fondness for scenes of natural beauty. Calderon is a representative of many a Spanish poet who does not think it beneath his dignity to convey to others some of the impressions which the vision of a lovely landscape has made upon the mind. Camoens in his Lusiad proves that this is true for Portugal also. In the fourteenth and fifteenth centuries travelers were careful to describe the strangeness and at the same time the attractions of the regions they visited. Thus the way was prepared for Columbus, who had the ability to give a description in a single luminous sentence which lingers in the mem-

ory, and creates a desire to see for oneself the places of which he writes. Humboldt thinks that landscape painting was not without an influence on early attempts to write out descriptions of nature. Landscape gardening made its contributions also, through the rare plants and trees, flowers and fruits, it presented to the eye. But the work of others is only an incentive to Humboldt to see with his own eyes and to set forth in picturesque language the features and striking characteristics of the countries in which he has lived. In doing this he is careful to show the effect of climate and the physical features of a country upon the well-being of men, for even he can not forget that it is for man that this world exists, and that it is to be studied for his sake and not for itself alone.

Astronomy, as known prior to the second half of the nineteenth century, receives extensive treatment in the "Cosmos." With its history and with the character and acquirements of the men who from the days of Aristarchus of Samos had been scanning the heavens and penetrating into the secrets of the starry worlds, Humboldt had made himself thoroughly familiar. What would he have said had he been as familiar with the principles of astrophysics? More ready than ever, assuredly he would have been, to assert his belief that we are standing on the threshold of a new era in scientific knowledge, and of discoveries which can not fail greatly to extend the horizon of our vision.

If he is careful to give credit to the early scientists with their limited acquirements, he is none the less so in his reference to the men of his day. Of Ehrenburg, his companion on his Asiatic journey, and a friend from whom he often received aid, he speaks as "the greatest microscopist of the age," "the highest authority in the study of microscopic organisms." Ehrenburg was one of the young men in whom Humboldt took deep interest. He was born at Delitsch in 1795 and died in Berlin, 1876. From 1820 to 1825 he was engaged in explorations in Egypt, Abyssinia and Palestine, and from 1838 to 1854 gave his attention almost exclusively to the study of microscopic organisms. For a translation from a Japanese Encyclopedia of an article on volcanoes Humboldt gives grateful recognition to Stanislaus Julien and prints it in full in Vol. V. of the "Cosmos." He refers to his brother William, whose death he mourned as long as he lived, as half his life, as an authority, as his treatise on the Kawi language shows, in the science of the comparative study of languages. Professor Waagen, of whose information he often makes use, the director of the gallery of painting in Berlin, is declared to be "a profound and cautious connoiseur of art." Generous praise is given Ottfried Müller, author of the "Archeologie der Kunst." Of Goethe and Schiller he speaks in terms which not only indicate his high esteem for their abilities, but the intimacy of his relations with them. Ludwig Tieck is an honored correspondent who has answered his questions concerning Calderon's and Shakespeare's de-

scriptions of nature. Of August de Chateaubriand, who died July 4, 1848, he speaks as his "old friend, famous for his descriptive powers." Nor does he fail to speak of Arago in the most affectionate terms, quotations from whose letters fill many pages of notes, and for whose attainments he had profound respect.

Humboldt begins his work with a description of celestial phenomena and then comes down to the earth. He refers with respect to the labors of Hipparchus, Eratosthenes and Euclid, as of mathematicians of the first rank. He credits Aristarchus of Samos with having anticipated Copernicus in his theory of the universe. He recognizes the value of Strabo's geography, written after its author had entered his eighty-third year, and makes use of the works of the Plinys, the elder and the younger. To Hipparchus of Sicily, and Galen of Pergamos, physician and anatomist, he refers as men of the highest attainments. He praises the Arabs not only for their observations of the heavens and their careful mathematical calculations, but for their skill in chemistry and their experiments in order to discover its value in medicine. He says they were acquainted with many of the qualities and uses of sulphuric and nitric acid, and were aware of the fact that bodies can be decomposed and reunited. He is at pains to show how nearly related to each other most discoveries are, and that they are made in almost every instance by men who miss only by a little the discovery of some great truth which a little while after, other more fortunate men see. Preparations, Humboldt tells us, for the voyages of great sailors just before Columbus were made in the twelfth century. Three men in the thirteenth century, Roger Bacon, Albertus Magnus and Vincentius of Beauvais, would have been eminent in any century. As independent thinkers, Duns Scotus, William of Occam and Nicolas of Cusa led the thought of the world from the time of Ramus, Campanella and Bruno to Descartes. It was in 1250 that Vincentius wrote his "Secula Naturæ" for the use of St. Louis and his queen Margaret. This and other works of his were forerunners of of the "Margarita Philosophia" of Father Reisch, published in 1486, a book which Humboldt praises and of which he made some use and which he declares was instrumental in diffusing knowledge in the last half of the fifteenth century. Of the writings of Father Joseph Acosta, the Jesuit who published his "Natural History of the Indies" in 1590, it is enough to say that they prepared the way for works of Vossius, which Newton used, and in which Humboldt finds the groundwork of physical geography. Many events which were of importance in his day Humboldt traces back to the fifteenth and the beginning of the sixteenth centuries. These are the doubling of the Cape of Good Hope by Vasco di Gama, the discovery of America by Columbus, the voyages of Amerigo Vespucci and his son, and Magellan's circumnavigation of the globe. That same period witnessed a rare manifestation of intellectual power as well as the growth

of a desire for religious freedom. It was in this period that the Laocoon, the Torso of Hercules, the Apollo Belvidere, the Medicean Venus were rediscovered. Michael Angelo was living in Rome, Leonardo da Vinci in Venice. It was the period of Titian and Raphael, of Holbein and Albert Dürer. Fourteen years after the discovery of the new world, or in the year that its discoverer died (1507), Copernicus made known his system of the world. Almost immediately followed an era of invention and the skilful use of instruments of research. New wonders in the heavens were constantly appearing. The results of mathematical calculations made astronomy an exact science. The law of gravitation, Kepler's laws of motion, knowledge of the pressure of the atmosphere, of the propagation of light, its laws of refraction and polarization, the radiation of heat, electro-magnetism, re-entering currents, vibration chords, capillary attraction, in their discovery and in the increase of knowledge concerning their nature and importance, are all closely connected. Galileo, Lord Bacon, Tycho Brahe, Descartes, Huyghens, Fermat, are more nearly related to each other in the work they each accomplish than is generally understood.

A list of some of the subjects treated in Volume I. of "Cosmos" will give a hint of the wealth of learning it contains and of the ability of the author to bring together a vast amount of knowledge on a great variety of topics without confusing his readers or for a moment permitting them to lose sight of his purpose to show how all knowledge is related and that the heavens and the earth belong to the same general plan, and are under the government of a single intelligent will. Beginning with a review of what is known of celestial phenomena, he comes down to those which are terrestrial in their character. Under celestial phenomena sidereal systems are treated as well as the solar system. Comets are carefully considered, aerolites, also, the zodiacal light and the milky way with its starless openings. Under terrestrial phenomena are grouped such subjects as the distribution of mountain chains, great plains, arid and fertile, oceans, inland seas, lakes, rivers, the figure of the earth, its internal heat, terrestrial magnetism, the aurora borealis, geognostic phenomena, earthquakes, gaseous emanations, hot springs, salses, volcanoes, isolated, in groups, and along certain lines, paleontology, geognostic periods in the earth's history with reference to certain marked changes in the physical features of the globe, atmospheric pressure, meteorology, the snow line of mountains, hygrometry, atmospheric electricity, organic life, the geographical distribution of plants and animals, of races of men and of language. One can see from this enumeration of titles how broad is the outlook over the world of knowledge in this little volume of less than 400 duodecimo pages. On every subject treated Humboldt either gives his own opinions or those of men whom he deems competent to speak. On astronomy we have not only what the ancients have thought, and the astrol-

ogists, but what the Herschells, Maedler, Arago, Leverrier, Laplace, Bessel of Königsberg, an authority on comets, and Faye, discovered and taught. Aerolites, shooting stars, fire balls, meteoric stones, are given extensive treatment. Aerolites are said to be "small bodies revolving with planetary velocity, and in obedience to the law of general gravity, in conic sections round the sun." Showers of shooting stars were observed by Humboldt and his companions in Cumana, S. A., in 1799 and in 1832–33 by Professor Denison Olmstead, of New Haven, Ct. To the consideration of this phenomena men like Brandes, Benzenberg, Bessel, Arago, Eduard Biot, Poisson, the mathematician, and Berzelius, the chemist, gave much time and thought.

The first person to observe and report upon the zodiacal light, according to Humboldt, was Dominique Cassini, of Bologna. He published his views in 1668. About this time the phenomenon was observed in Persia by Chardin, the traveler. Laplace, Schubert, Poisson and Sir John Herschell regarded the phenomenon with deep interest and sought a satisfactory solution for it. From Sir John Herschell at the Cape of Good Hope came the suggestion that the milky way could be broken up into well-defined sections and that with sufficiently powerful telescopes all its nebulæ could be resolved into stars. Humboldt himself directs attention to so-called "starless openings" in the milky way through which one looks out into empty space.

Before Humboldt died there were a large number of competent observers of terrestrial phenomena. It was taken for granted as needing no proof that the interior of the earth is liquid and of high temperature, and that this heated melted matter has acted, and continues to act, upon the surface of the earth. It was believed that the depths of the sea correspond in general with the heights of the mountains, and that our power to study the surface of the earth is limited to about the distance of 48,000 feet. The history of volcanoes, traced from the days of Plato, Aristotle, Ovid, Pliny to Daubeny, whose treatise on the subject (Paris, 1848) Humboldt accepts as the best ever written, leads him to propound opinions of his own and to compare them with suggestions made by Darwin in his account of his cruise in the ship *Beagle*. He places a high estimate on the value of the measurements by the pendulum of Sir Edward Sabine as a means of determining the figure of the earth. From his voyage in 1822 and 1823 much was learned about magnetism in general and terrestrial magnetism in particular. To the establishment of what were deemed by Humboldt sound theories concerning the internal heat of the earth, Fourier, Biot, Laplace and Poisson made large contributions. The mathematical calculations of Friedrich Gauss and Weber were accepted as of the first importance in the study of magnetism. The oscillations of the magnetic needle were observed and noted in different parts of the world. Humboldt himself says in a note, Vol. I., p. 187: "I regard the discovery of the law of the

decrement of magnetic force from the poles to the equator as the most important result of my American voyage." The subject arrested the attention of the British Association, which made special arrangements for its careful study. While living at Quito, Humboldt gave what he deemed first-hand study to the nature and cause of earthquakes and arrived at conclusions which were strengthened, as he believed, by similar studies in the same region by Bousingault, twenty-three years later. Bousingault's treatise on earthquakes, Humboldt accepted as the best and most authoritative ever written. Its theories will hardly be regarded as final by scientists of our time. Rocks, Humboldt declares, without any qualification are in the process of formation and disintegration. He divides them into eruptive, sedimentary, metamorphic and conglomerate rocks. The importance of the subject of paleontology is recognized in "Cosmos," but is treated almost as if it were a new science. Agassiz's work on "Fossil Fishes," in which more than 1,700 species were described, is given the honor it deserves. But open minded as Humboldt was to every suggestion of scientific men and ready to accept any well-authenticated statement, he was very cautious about departures from old and prevailing theories. Since his time, meteorology, as he predicted it would, has become a science of much practical value. Geology, mineralogy and paleontology have made giant strides. Chemistry has almost entirely changed its character, even its terminology has become new. The advance in physics almost defies description. Since Humboldt died Lord Kelvin, Clerk Maxwell of Edinburgh and Herz of Germany have done their epoch-making work on light. Lines of magnetic force and the character of the magnetic field are better understood than when Faraday gave his attention to them and through his discoveries received the warmest praise from Humboldt. Electricity as a science and in its practical applications has developed one might say almost entirely since 1859. Of radium and radio-activity, whose secrets Monsieur and Madame Curie and Rutherford have done so much to make known, Humboldt knew nothing. Nor had he any conception of the character and extent of the revelations from the heavenly bodies which studies in astro-physics have brought. But of science as it was in his day, and for some years after his death, he was a master and as competent as he himself believed and as others admit him to have been to make such general statements concerning its triumphs and promise as to show the careful reader of "Cosmos" even now the foundations upon which the scientific progress of the last half century has rested.

A REVIEW OF THREE FAMOUS ATTACKS UPON THE STUDY OF MATHEMATICS AS A TRAINING OF THE MIND

By Professor FLORIAN CAJORI
COLORADO COLLEGE

NO doubt the most famous attack that has ever been made upon mathematics and its educational value was published in 1836 in the *Edinburgh Review* by Sir William Hamilton, professor of logic and metaphysics at Edinburgh. He must not be confounded with his contemporary, Sir William Rowan Hamilton, the inventor of quaternions. The first reading of that article by the Edinburgh philosopher makes one feel as if in an earthquake in which one's most cherished pedagogic structures are tumbling into a heap and the very foundations are being removed from under one's feet. With the strength of a superhuman giant Hamilton seems to hurl facts with unerring destructive power against the most massive educational castles of his day. The lack of utility of mathematical study, as a training of the mind, is shown by quotations from an array of authorities, gathered from all ages and nations of the civilized world, and the reader is utterly overwhelmed by this "cloud of witnesses."

Upon a second reading of Hamilton's essay one begins to see signs of weakness; an attempt to verify his quotations discloses superficiality and carelessness in the selection of representative quotations from his witnesses. I know of only one mathematician who has made an extended reply to Hamilton, though several have criticized certain parts of his essay. This extended reply is found in an article by A. T. Bledsoe in the *Southern Review* for July, 1877. Bledsoe, a graduate of West Point, was before the civil war professor of mathematics at Kenyon College, then at Miami University, and finally at the University of Virginia. Later he became editor of the *Southern Review*. His reply to Hamilton was printed in the year of his death. It was written after a most careful examination of the authorities cited by Hamilton. It is a very able article, but so far as I have been able to ascertain, it has completely escaped the attention of mathematicians. We can recommend it as interesting and even now worth reading.

A few years ago the noted German mathematician, Alfred Pringsheim, wrote a popular address on the "Utility and Alleged Inutility of Mathematics."[1] Pringsheim, in referring to Hamilton's article,

[1] "Ueber den Wert und angeblichen Unwert der Mathematik," Von Alfred Pringsheim, Muenchen, 1894.

writes down the names of a dozen authorities cited by Hamilton, and then says: "I am ashamed to confess that before reading Hamilton's article I did not know a single one of these great authorities even by name; an extenuating circumstance is the fact that some of these names I could not find even in the scientific directories." However, Hamilton does quote from several noted mathematicians—D'Alembert, Descartes, Pascal, Dugald Stewart—men whose opinions are worthy of serious consideration and study.

Let us now take up Hamilton's essay. It takes the form of a review of William Whewell's "Thoughts on the Study of Mathematics as a Part of a Liberal Education," published in 1835. Whewell was at that time fellow and tutor in Trinity College, Cambridge. Later he became head master of Trinity. At that time the University of Cambridge was laying unusual stress upon mathematics; mathematical skill was the chief requirement in the tripos examinations. Hamilton looked upon the Cambridge plan with disfavor and seized upon Whewell's small pamphlet as a pretext to enter upon a demonstration of the inutility of mathematical study as an exercise of the mind.

In every dispute it is necessary to state the issue clearly and then to adhere to it steadily. The issue is thus stated by Hamilton:[2]

> Before entering on details, it is proper here, once for all, to premise,—in the first place, that the question does not regard the value of mathematical *science*, considered in itself, but the utility of mathematical *study*, as an exercise of the mind; and in the second, that the expediency is not disputed of leaving mathematics, as a coordinate, to find its level among the other branches of academical instruction. It is only contended that they ought not to be made the *principal*, far less the *exclusive* object of encouragement. We speak not of *professional*, but of *liberal* education.

This statement of the issue is quite clear. Moreover, the position taken here is quite fair. Few educators of the present time would take marked exception to it. Mathematics was to occupy a coordinate position in the curriculum with other studies. But Sir William soon forgets his position. He does not adhere to the point of dispute, as laid down by himself, but proceeds to prove that mathematics is "not an improving study." He says:[3]

> If we consult reason, experience and the common testimony of ancient and modern times, none of our intellectual studies tend to cultivate a smaller number of the faculties, in a more partial manner, than mathematics.

He proceeds to adduce testimony to the effect that[4]

''the cultivation afforded by the mathematics is, in the highest degree, one-sided and contracted,'' that mathematics ''freeze and parch the mind,''[5] that this

[2] *Edinburgh Review*, Vol. 62, 1836, p. 411.

[3] *Loc. cit.*, p. 419.

[4] *Loc. cit.*, p. 421.

[5] *Loc. cit.*, p. 421.

[6] *Loc. cit.*, p. 421.

science is "absolutely pernicious as a mean of internal culture,"[6] that an "excessive" study of the mathematical sciences "absolutely incapacitates the mind, for those intellectual energies which philosophy and life require. We are thus disqualified for *observation either internal or external*—for *abstraction and generalization*—and for *common reasoning;* and disposed to the alternative of blind *credulity* or irrational *scepticism.*"[7] Further on Hamilton says that mathematics can not "conduce to 'logical habits' at all. The art of reasoning *right* is assuredly not to be taught by a process in which there is no reasoning *wrong.*"[8] "But if the study of mathematics do not, as a logical discipline, warn the reason against the fallacies of thought, does it not," inquires Hamilton,[9] "as an invigorating exercise of reason itself, fortify that faculty against their influence?"

To this, Hamilton says, "it is equally incompetent."[10] He next observes "that to minds of any talent, mathematics are *only difficult because they are too easy,*"[11] that "in mathematics dullness is thus elevated into talent, and talent degraded into incapacity."[12] "Of Observation, Experiment, Induction, Analogy, the mathematician knows nothing."[13] "After all," says Hamilton,[14] "we are afraid that D'Alembert is right; mathematics may distort, but can never rectify, the mind."

From these quotations it appears that Hamilton tried to prove that the study of this science is positively injurious to the mind. If this be true, then, of course, mathematics ought to be excluded entirely from a scheme of liberal education, unless, as Bledsoe says,[15] the object of such a scheme be to injure, and not to benefit, the mind of the student. Had Hamilton adhered to the position which he first outlined, he could have entrenched himself behind practically unconquerable breastworks. But what has given notoriety to his paper, is the fact that most of the time he really argues against mathematical study altogether by endeavoring to show that its effect upon the mind is injurious. For seventy-five years Hamilton's article has been singled out as the most powerful argument in existence against mathematics.

To show the alleged pernicious effect of mathematics upon the mind Hamilton's argument proceeds along two principal lines, the first of which is the contention that mathematicians who have confined their studies to mathematics alone are addicted to blind credulity or irrational scepticism and, in general, lack good judgment in affairs of life.

It is my opinion that Hamilton establishes this proposition. The *mere* mathematician is a man of one-sided development. But how about the metaphysician who confines his studies to metaphysics alone?

[7] *Loc. cit.*, p. 424.
[8] *Loc. cit.*, p. 427.
[9] *Loc. cit.*, p. 428.
[10] *Loc. cit.*, p. 428.
[11] *Loc. cit.*, p. 430.
[12] *Loc. cit.*, p. 430.
[13] *Loc. cit.*, p. 433.
[14] *Loc. cit.*, p. 453.
[15] *Southern Review*, Vol. 22, 1877, p. 261.

Is he an all-round man? Is the caveling metaphysician, who disputes all things, very far ahead of the credulous mathematician? Had Hamilton been disposed to attack the study of metaphysics, could he not have made as strong a case against metaphysics as he did make against mathematics? The *mere* metaphysician and the *mere* mathematician are one-sided individuals. How about the *mere* philologist with his roots and stems, the *mere* paleontologist with his old bones, the *mere* physicist with his moment of inertia and latent heat, the *mere* chemist with his pedantic formulæ, the *mere* entomologist with his drawings of beetles? The truth is that the exclusive study of any branch of knowledge is to be discouraged as undesirable for a liberal education. Every one recognizes the dangers of premature and excessive specialization. But because a certain branch of study, taken by itself, fails to accomplish fully all the ends of education, are we to draw the inference that this branch of study is injurious? Because the human body can not readily subsist upon a diet consisting exclusively of roast beef, are we to conclude from this fact alone that roast beef is unhealthy and ought to be banished from the dining table? Yet this is exactly the mode of argument which Hamilton applies to mathematics. Plenty of people are willing to testify that mathematics is not the sole and exclusive intellectual diet that a growing boy should have. From testimony of this sort Hamilton attempts to argue that "mathematics may distort, but can never rectify, the mind."[16] In our humble opinion the learned philosopher is guilty of a very unphilosophical argument, "unphilosophical in its design, in its spirit, and in its execution."[17]

We said that Hamilton argues along two principal lines. His second mode of attack is to show that many mathematicians, some of them of great eminence, have found mathematics unsatisfactory as an exercise of the mind, and have renounced it. I hardly know how to approach this part of Hamilton's argument. For lack of space I can not demonstrate the conclusions we are about to state. Bledsoe's reply to Hamilton covers sixty-nine pages, and for details we must refer you to him and to the authorities quoted by Bledsoe and Hamilton. By his extensive inquiry Bledsoe proves what some other writers before him hinted at, or proved only in part, namely, that Hamilton was extremely careless in the selection of his quotations. By means of partial extracts, badly chosen, he made scientists say exactly the opposite of their real sentiments. Bledsoe convicts Hamilton of this practise in his quotations from D'Alembert, Pascal, Descartes and Dugald Stewart, who are the most celebrated mathematical witnesses called by Hamilton.

Take the case of Descartes. We quote from Hamilton the following:[18]

[16] *Loc. cit.*, p. 453.
[17] *Southern Review*, Vol. 22, p. 282.
[18] *Loc. cit.*, p. 421.

Nay, Descartes, the greatest mathematician of his age, and in spite of his mathematics, also its greatest philosopher, was convinced from his own consciousness, that these sciences, however valuable as an instrument of external science, are absolutely pernicious as a mean of internal culture. "It was now a long time" (says Baillet, his biographer under the year 1623, the 28th of the philosopher) "since he had been convinced of the small utility of the mathematics, especially when studied on their own account, and not applied to other things. There was nothing, in fact, which appeared to him more futile than to occupy ourselves with simple numbers and imaginary figures, as if it were proper to confine ourselves to these trifles (bagatelles) without carrying our view beyond. There even seemed to him in this something worse than useless. His maxim was, that such application insensibly disaccustomed us to the use of our reason, and made us run the danger of losing the path which it traces." ("Cartesii Lib. de Directione Ingenii," Regula 4, MS.) "In a letter to Mersenne, written 1630, M. DesCartes recalled to him that he had renounced the study of mathematics for many years; and that he was anxious not to lose any more of his time in the barren operations of geometry and arithmetic, studies which never lead to anything important." Speaking of the general character of the philosopher, Baillet adds, "In regard to the rest of mathematics [he had just spoken of astronomy, which Descartes thought, 'though he dreamt in it himself, only a loss of time'], those who know the rank which he held above all mathematicians, ancient and modern, will agree that he was the man in the world best qualified to judge them. We have observed that, after having studied them to the bottom, he had renounced those of no use for the conduct of life, and the solace of mankind."[19]

"The study of mathematics" (says Descartes, and he frequently repeats the observation) "principally exercises the imagination in the consideration of figures and motions."[20] Nay, on this very ground, he explains the incapacity of mathematicians for philosophy. "That part of the mind," says he, in a letter to Father Mersenne, "viz., the imagination, which is principally conducive to a skill in mathematics, is of greater detriment than service for metaphysical speculations."[21]

These are Hamilton's references to Descartes which contain quotations from Descartes or his biographer Baillet. Evidently Hamilton was guided more by what Baillet stated about Descartes than upon what Descartes himself actually said. The letters to Mersenne simply show that Descartes was not inclined to confine his activities to mathematics, nor ready to admit that mathematical training alone constituted adequate preparation for the study of philosophy. In quoting from Descartes's "Rule Four" for conducting philosophical inquiries, Bledsoe puts into italics the passage garbled by Hamilton and Baillet. It can thus be easily read in connection with what immediately precedes and follows, and one can readily see how Hamilton's extract, by itself, conveys an impression quite the opposite of that conveyed by the entire passage. Descartes gives an exposition of his method of philosophical inquiry. He says that he wishes to apply his method not merely to the ancient "arithmetic and geometry," but to other sciences

[19] "La Vie de Descartes," P. I., pp. 111, 112, 225; P. II., p. 481.

[20] "Lettres," P. I., let. xxx.

[21] *Loc. cit.*, p. 426.

where progress has been hitherto arrested. To apply it to arithmetic and geometry alone would be to occupy himself with "trifles," not only because of the narrow field of application, but also because what was practically his method had been thus applied long ago by the Greeks. He wished to direct his method to unsolved problems. But he is free to acknowledge that his method is found in mathematics as in an envelop. "Now I say that the mathematics are the envelope of this method, not that I wish to conceal and envelop it, in order to keep the vulgar away from it; on the contrary, I wish to dress and adorn it, in such manner that it may be more easily grasped by the mind."[22]

In all this there is no attack whatever upon the culture value of mathematics. Instead of hostility he shows friendliness to mathematics as a gymnast of the mind. In his discussion of the "Fourth Rule" there is a passage, not quoted by Hamilton, which bears directly upon the question at issue: "This is why I have cultivated even to this day, as much as I have been able, that universal mathematical science, so that I believe I may hereafter devote myself to other sciences, without fearing that my efforts may be premature."[23] Here then Descartes declares that, as much as possible, he had studied mathematics all his life, as a preparation or propædeutic to philosophy. It appears that Descartes looked upon mathematical study as a desirable preparation to philosophy, just as Plato had done nearly 2,000 years earlier. Looking at the testimony contained in Descartes's writings, as a whole, there is nothing in it to disturb in the least the belief in the educational value of mathematical study.

As a side issue we touch upon Hamilton's assertion that Descartes in 1623 renounced mathematics for good. Hamilton does not say that the work which is memorable in the history of mathematics as the creation of analytical geometry was published by Descartes 14 years later, in 1637. Did Descartes renounce mathematics for good? The life of Descartes which was prepared by M. Thomas, a biography which captured the prize offered by the French Academy in 1765, a biography which is placed first in Cousin's edition of the works of Descartes, says this about Descartes's renunciation (p. 89): "He attempted at least five or six times to renounce them, but he always returned to them again." M. Thomas adds: "He wished to occupy himself henceforth only with morals; but on the first occasion he returned to the study of nature. Borne away in spite of himself, he plunged anew into the abstract sciences" (p. 92).

I proceed now to a review of a second attack upon mathematical study, made by Schopenhauer, the pessimistic sage of Frankfort-on-the-Main. His thoughts on mathematics are expressed in his work, entitled, "The World as Will and Idea," as it appeared in its second edi-

[22] *Southern Review*, Vol. 22, p. 270.

[23] *Southern Review*, Vol. 22, p. 271.

tion, 1844. Schopenhauer's views must have attracted considerable attention in Germany, for as late as 1894 Alfred Pringsheim thought it necessary to refute his argument, and only four years ago Felix Klein referred to him at some length in a mathematical lecture at the University of Goettingen. Schopenhauer had read Sir William Hamilton, as appears from the following passage:[24]

I rather recommend, as an investigation of the influence of mathematics upon our mental powers, . . . a very thorough and learned discussion, in the form of a review of a book by Whewell in the *Edinburgh Review* of January, 1836. Its author, who afterwards published it with some other discussions, with his name, is Sir W. Hamilton, Professor of Logic and Metaphysics in Scotland. This work has also found a German translator, and has appeared by itself under the title, "Ueber den Werth und Unwerth der Mathematik, aus dem Englischen," 1836. The conclusion the author arrives at is that the value of mathematics is only indirect, and lies in the application to ends which are only attainable through them; but in themselves mathematics leave the mind where they find it, and are by no means conducive to its general culture and development, nay, even a decided hindrance. This conclusion is not only proved by thorough dianoiological investigation of the mathematical activity of the mind, but is also confirmed by a very learned accumulation of examples and authorities. The only direct use which is left to mathematics is that it can accustom restless and unsteady minds to fix their attention. Even Descartes, who was yet himself famous as a mathematician, held the same opinion with regard to mathematics.

These words of Schopenhauer are an unqualified endorsement of Hamilton, the only such endorsement with which I happen to be familiar.

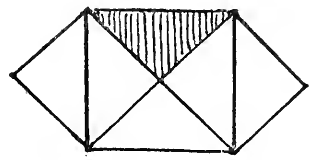
Schopenhauer's own argument is mainly directed against Euclid and his geometrical demonstrations. Schopenhauer had his own ideas as to how absolute truth can be reached; these ideas did not agree with the method of Euclid. Our German philosopher says:[25]

If now our conviction that perception is the primary source of all evidence, and that only direct or indirect connection with it is absolute truth; and further, that the shortest way to this is always the surest, as every interposition of concepts means exposure to many deceptions; if, I say, we now turn with this conviction to mathematics, as it was established as a science by Euclid, and has remained as a whole to our own day, we can not help regarding the method it adopts as strange and indeed perverted. We ask that every logical proof shall be traced back to an origin in perception; but mathematics, on the contrary, is at great pains deliberately to throw away the evidence of perception which is peculiar to it, and always at hand, that it may substitute for it logical demonstration. This must seem to us like the action of a man who cuts off his legs in order to go on crutches . . . (page 92). We are compelled by the principle of contradiction to admit that what Euclid demonstrates is true, but we do not comprehend *why* it is so. We have therefore almost the same uncomfortable feeling that we experience after a juggling trick, and, in fact, most of Euclid's demonstrations are remarkably like such feats. The truth almost always enters by the back door, for it manifests itself *par accidens* through some contingent circumstance.

[24] A. Schopenhauer, "The World as Will and Idea," translated by R. B. Haldane and J. Kemp, Vol. II., London, 1891, p. 323.

[25] *Loc. cit.*, Vol. I., 1891, par. 15, p. 90.

Often a *reductio ad absurdum* shuts all the doors one after another, until only one is left through which we are therefore compelled to enter. Often, as in the proposition of Pythagoras, lines are drawn, we don't know why, and it afterwards appears that they were traps which close unexpectedly and take prisoner the assent of the astonished learner . . . (page 94). Euclid's logical method of treating mathematics is a useless precaution, a crutch for sound legs . . . (page 95). The proposition of Pythagoras teaches us a *qualitas occulta* of the right-angled triangle; the stilted and indeed fallacious demonstration of Euclid forsakes us at the *why*, and a simple figure, which we already know, and which is present to us, gives at a glance far more insight into the matter, and firm inner conviction of that necessity, and of the dependence of that quality upon the right triangle:



In the case of unequal catheti also, and indeed generally in the case of every possible geometrical truth, it is quite possible to obtain such a conviction based on perception . . . (page 96). It is the analytical method in general that I wish for the exposition of mathematics, instead of the synthetical method which Euclid made use of.

In the above we have Schopenhauer's famous characterization of mathematical reasoning as "mouse-trap proofs" (Mausefallenbeweise). These quotations and other passages which space does not permit us to quote indicate that his objections are directed almost entirely against Euclid. Schopenhauer discloses no acquaintance with such modern mathematical concepts as that of a function, of a variable, of coordinate representation, and the use of graphic methods. With him Euclid and mathematics are largely synonymous. Because of this one-sided and limited vision we can hardly look upon Schopenhauer as a competent judge of the educational value of modern mathematics.

If Schopenhauer's criticism of Euclid is taken as the expression of the feelings, not of an advanced mathematician, but of a person first entering upon the study of geometry and using Euclid's "Elements," then we are willing to admit the validity of Schopenhauer's criticisms, in part. Euclid did not write his geometry for children. It is a historical puzzle, difficult to explain, how Euclid ever came to be regarded as a text suitable for the first introduction into geometry. Euclid is written for trained minds, not for immature children. Of interest is Schopenhauer's reference to the method of proof, called the *reductio ad absurdum*. The experience of teachers with this method has been much the same in all countries. Some French critics called it a method which "convinces but does not satisfy the mind." De Morgan says: "The most serious embarrassment in the purely reasoning part is the *reductio ad absurdum*, or indirect demonstration. This form of argument is generally the last to be clearly understood, though it occurs almost on the threshold of the 'Elements.' We may find the key to the difficulty in the confined ideas which prevail on the modes of speech there employed."

On the main idea of what mathematical proof should be, the mathematician can hardly agree with Schopenhauer. Schopenhauer considers a succession of separate logical conclusions, which are contained in a rigorous mathematical proof, as insufficient and unendurable; he wants to be convinced of the truth of a theorem instantaneously, by an act of *intuition.* He advances the theory that, besides the severely logical deductions there is another method of proving mathematical truths, that of direct perception and intuition. We agree with Schopenhauer that intuition should play an important part, especially in preliminary courses, before children enter upon courses in demonstrative geometry; but eventually the logical proof must be made to follow before we are prepared to accept a proposition as established. Schopenhauer directs his criticisms particularly against Euclid's proof of the Pythagorean Theorem and then offers his own proof, which is practically the same as the Hindu proof and can be given by drawing the figure and then explaining, as did the Hindus, "Behold." But Schopenhauer's is not a *general* proof; it holds only for a special case, namely, for the isosceles right triangle.

Really, Euclid's proof of the Pythagorean Theorem consists of a number of steps, each of which is quite evident to the eye. Thus a square is represented as the sum of two rectangles, which is an intuitive relation. Then each rectangle is shown to be equal to double a triangle of the same base and altitude. This again the child accepts the more readily as more or less intuitively evident. And so on. Every step appears quite reasonable to one depending on intuition alone. It does seem as if Schopenhauer could have made a better selection from Euclid for his point of attack.

From what we have said it appears that Schopenhauer's attack bears only indirectly upon the question relating to the mind-training value of mathematics; his criticism is focused directly upon questions of logic, of mode of argumentation and of sufficiency of proof.

I pass now to a third attack upon mathematics, made in 1869 by the naturalist, Thomas H. Huxley. So far as I know, Huxley was not influenced either by Hamilton or Schopenhauer, though the words he used remind us of a sentence in Hamilton. Hamilton had said: "Of Observation, Experiment, Induction, Analogy, the mathematician knows nothing."[26] Huxley, in the June number of the *Fortnightly Review,* 1869, said: Mathematics is that study "which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation."[27] Huxley and Hamilton both name observation, experiment, induction, but they differ in the fourth process. Hamilton says "analogy"; Huxley says "causation."

In the same year there appeared in print an after-dinner speech de-

[26] *Edinburgh Review,* Vol. 22, p. 433.

[27] *Fortnightly Review,* London, Vol. 5, 1869, p. 667.

livered by Huxley before the Liverpool Philomathic Society[28] in which he argued in favor of scientific education, as follows:

The great peculiarity of scientific training, that in virtue of which it can not be replaced by any other discipline whatsoever, is the bringing of the mind directly into contact with fact, and practising the intellect in the completed form of induction; that is to say, in drawing conclusions from particular facts made known by immediate observation of nature.

The other studies which enter into ordinary education do not discipline the mind in this way. Mathematical training is almost purely deductive. The mathematician starts with a few simple propositions, the proof of which is so obvious that they are called self-evident, and the rest of his work consists of subtle deductions from them. The teaching of languages, at any rate as ordinarily practised, is of the same general nature—authority and tradition furnish the data, and the mental operations of the scholar are deductive.

It will be noticed that these remarks were made at a time when there was a conflict on the question of educational values between the classics and mathematics, on one side, and the natural and social sciences, on the other. This makes it evident that Huxley appeared in this discussion in the capacity of an advocate rather than as a judge.

Of great interest, in connection with Huxley's utterances is the reply made to him by the mathematician J. J. Sylvester. To Americans Sylvester's name is memorable, because at one time he was on the faculty of the University of Virginia and, when the Johns Hopkins University opened in 1876, Sylvester again came over from England and for eight years lectured to American students on modern higher algebra. He gave a powerful stimulus to the study of higher mathematics in this country. Sylvester was an enthusiast. His reply to Huxley was the subject of his presidential address to the mathematical and physical section of the British Association, meeting at Exeter in 1869. This address is of special value, because it is largely autobiographical; it tells how Sylvester carried on his researches in mathematics, how he came to make some of his discoveries. By his own experiences as a mathematical investigator he tried to show that Huxley's description of mathematical activity was incorrect. We can do no better than quote rather freely from Sylvester's memorable address. He says:

I set to myself the task of considering certain recent utterances of a most distinguished member of this Association, one whom I no less respect for his honesty and public spirit than I admire for his genius and eloquence, but from whose opinions on a subject which he has not studied I feel constrained to differ. Göthe has said:

> ''Verständige Leute kannst du irren sehn:
> In Sachen, nämlich, die sie nicht verstehn.''
> ''Understanding people you may see erring
> In those things, to wit, which they do not understand. . . .''

He [Huxley] says ''mathematical training is almost purely deductive. The mathematician starts with a few simple propositions, the proof of which is so

[28] *Macmillan's Magazine*, Vol. 20, London, 1869, pp. 177–184.

obvious that they are called self-evident, and the rest of his work consists of subtle deductions from them. The teaching of languages, at any rate as ordinarily practised, is of the same general nature—authority and tradition furnish the data, and the mental operations are deductive.'' It would seem that from the above somewhat singularly juxtaposed paragraphs that, according to Professor Huxley, the business of a mathematical student is from a limited number of propositions (bottled up and labelled ready for future use) to deduce any required result by a process of the same general nature as a student of language employs in declining and conjugating his nouns and verbs—that to make out a mathematical proposition and to construe or parse a sentence are equivalent or identical mental operations. Such an opinion scarcely seems to need serious refutation.

Further on Sylvester says:

We are told that ''mathematics is that study which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation.'' I think no statement could have been more opposite to the undoubted facts of the case; that mathematical analysis is constantly invoking the aid of new principles, new ideas and new methods, not capable of being defined by any form of words, but springing direct from the inherent powers and activity of the human mind, and from continually renewed introspection of that inner world of thought of which the phenomena are as varied and require as close attention to discern as those of the outer physical world, . . . that it is unceasingly calling forth the faculties of observation and comparison, that one of its principal weapons is induction, that it has frequent recourse to experimental trial and verification, and that it affords a boundless scope for the exercise of the highest efforts of imagination and invention.

Lagrange . . . has expressed emphatically his belief in the importance to the mathematician of the faculty of observation; Gauss has called mathematics a science of the eye . . .; the ever to be lamented Riemann has written a thesis to show that the basis of our conception of space is purely empirical, and our knowledge of its laws the result of observation, that other kinds of space might be conceived to exist subject to laws different from those which govern the actual space in which we are immersed. . . . Most, if not all, of the great ideas of modern mathematics have had their origin in observation. Take, for instance, . . . Sturm's theorem about the roots of equations, which, as he informed me with his own lips, stared him in the face in the midst of some mechanical investigations connected with the motion of compound pendulums.

After citing many other instances, Sylvester says:

I might go on, were it necessary, piling instance upon instance, to prove the paramount importance of the faculty of observation to the progress of mathematical discovery. Were it not unbecoming to dilate on one's personal experience, I could tell a story of almost romantic interest about my own latest researches in a field where Geometry, Algebra, and the Theory of Numbers melt in a surprising manner into one another, . . . which would very strikingly illustrate how much observation, divination, induction, experimental trial, and verification, causation, too (if that means, as I suppose it must, mounting from phenomena to their reasons or causes of being), have to do with the work of the mathematician. In the face of these facts, which every analyst in this room or out of it can vouch for out of his own knowledge and personal experience, how can it be maintained, in the words of Professor Huxley, who, in this instance, is speaking of the sciences as they are in themselves and without any reference to scholastic discipline, that Mathematics ''is that study which knows

nothing of observation, nothing of induction, nothing of experiment, nothing of causation.''

I, of course, am not so absurd as to maintain that the habit of observation of external nature will be best or in any degree cultivated by the study of mathematics, at all events as that study is at present conducted, and no one can desire more earnestly than myself to see natural and experimental science introduced into our schools as a primary and indispensable branch of education: I think that that study and mathematical culture should go on hand in hand together, and that they would greatly influence each other for their mutual good. I would rejoice to see mathematics taught with that life and animation which the presence and example of her young and buoyant sister could not fail to impart, short roads preferred to long ones, Euclid honourably shelved or buried ''deeper than e'er plummet sounded'' out of the schoolboy's reach, morphology introduced into the elements of Algebra—projection, correlation, and motion accepted as aids to geometry—the mind of the student quickened and elevated and his faith awakened by early initiation into the ruling ideas of polarity, continuity, infinity, and familiarization with the doctrine of the imaginary and inconceivable.

What light, if any, do these attacks and these defenses of mathematical study throw upon the educational problems of to-day? Hamilton gathered a cloud of witnesses which, in so far as the testimony adduced was sincere, proved that mathematical study alone is not the proper education for life. That mathematical study is pernicious Hamilton did not succeed in proving. It would seem, therefore, as if the Hamiltonian controversy was somewhat barren in useful results. Probably no one to-day advocates the well-nigh exclusive study of mathematics or of any other science as the best education obtainable.

Schopenhauer attacked mainly the logic of mathematics as found in Euclid. As a critique of the logic as used by Euclid the attack is childish and has no value for us. From the standpoint of educational method it points out the difficulty experienced by children in understanding the mode of proof called the *reductio ad absurdum* and emphasizes the constant need of appeal to the intuition in the teaching of mathematics.

The attack made by Huxley touches questions which are more subtle. Sylvester, in his rejoinder, proved conclusively that the mathematician engaged in original research does exercise powers of internal observation, of induction, of experimentation and even of causation. Are these powers exercised by the pupil in the class room? That depends. When English teachers required several books of Euclid to be memorized, even including the lettering of figures, no original exercises being demanded, then indeed such teaching knew nothing of observation, induction, experiment, and causation, except that a good memory as a cause was seen to bring about a pass mark as an effect. But when attention is paid to the solution of original exercises, and to the heuristic or genetic development of certain parts of the subject, then surely the young pupil

exercises the same faculties as does the advanced mathematician engaged in research.

The language used by Huxley and Sylvester is not in accord with some of the ideas of recent American psychologists, who declare that teachers should not attempt to train particular mental faculties. We have seen that Hamilton, Huxley and Sylvester discussed the training of the faculty of "observation," the "reasoning faculty" or the "power of observation." Hamilton complains that "none of our intellectual studies tend to cultivate a smaller number of the faculties, in a more partial manner, than mathematics."[29] Recent writers object to this point of view. The teacher must "stop wet-nursing orphan mental faculties"; his business is "to select points of contact between learning minds and the reality that is to be learned." The recent movement is a remarkable reaction against the time-honored "doctrine of formal discipline," which originated with the Greeks and probably reached its height in the time of Huxley. In its extreme form this is "the doctrine of the applicability of mental power, however gained, to any department of human activity."[30] In its place comes the doctrine of "specific disciplines," according to which "improvement of any one mental function or activity will improve others only in so far as they possess elements common to it also." The subject is still in the polemical stage. The new psychology is not hostile to mathematics, except perhaps to the formal or mechanical parts of algebra. A point which may harmonize in part the old and the new views, and which in itself demands very lively consideration, lies in the claim put forth recently, that the benefit to be derived from a subject like mathematics depends largely upon the attitude toward it maintained by the teacher and pupil. They should be controlled by ideals to be reached as a goal, such as ideals of accuracy, of efficiency, of scientific method. "If we have trained pupils to think rigidly in geometry, for example, how shall we insure an application of rigid thinking to situations that lack the geometrical elements? . . . Shall we not have the greatest assurance of such transfer, if the method has been made to appeal to the pupil as something thoroughly worth while?"[31] No doubt this feature has figured prominently in the mathematical teaching of all ages, but recent is the psychological recognition of it as a conscious factor in the transfer of special training to new fields of action.

[29] *Edinburgh Review*, Vol. 22, p. 419.

[30] W. H. Heck, "Mental Discipline and Educational Values," New York, 1909, p. 7 and other places.

[31] W. C. Bagley, "Educational Values," New York, 1911, p. 194.

THE RED SUNFLOWER

By Professor T. D. A. COCKERELL
UNIVERSITY OF COLORADO

ONCE upon a time, in England, a certain bishop visited a Sunday-school. Being asked to question the children, he inquired of a small and timid boy, "Who made the world?" Completely rattled, the child made no answer. The bishop asked a second time, and, again getting no result, exclaimed in some wrath, "Is it possible, my dear boy, that you don't know who made the world?" The youngster burst into tears, and declared earnestly, "Please, sir, I didn't do it, indeed I didn't do it!"

I have found this story useful in the discussions on the genesis of the red sunflower. The first question people ask is even more direct than that of the bishop, "How did you do it?" The answer is, "We did not do it, but—the author of the world is also the author of the red sunflower."

My wife and I have lived in New Mexico and Colorado for many years, and have seen, I suppose, millions of sunflowers. So far as we know, we had never seen a red one until 1910, nor had any one else, excepting some horticultural forms of a kind quite different from the ordinary plant. The summer before last, in Boulder, Colorado, there was a group of sunflowers growing by the road about a hundred yards from our house. Having occasion to cross the road, my wife noticed what she supposed to be a large butterfly, presumably one of the silver-spots, on a sunflower head. Glancing at the plant a little later, she was surprised to note that the butterfly had not moved, and approaching nearer to satisfy her curiosity, found the red sunflower. There was no butterfly; the red appearance was due to the rays, which were deeply suffused with a fine chestnut red. There was only one plant, and this close to the road, where hundreds of people passed daily. Already some one had picked a head as a curiosity. Evidently it was not safe to leave the plant where it was; it would almost surely be destroyed. We had had no experience in transplanting sunflowers, especially in full bloom, so we tried first with one of the common kind. Succeeding well, we carefully dug up the red one, and removed it to our garden. Here, on bended knees, it was carefully tended, and a contrivance was arranged to protect it at first from the direct rays of the sun. It soon recovered from the shock, and proceeded to bloom and go to seed in a normal way.

So far good: but now a difficulty arose. On looking up the literature, we found that Dr. G. H. Shull had experimented with sunflowers, and had found them invariably self-sterile. That is to say, no sunflower would produce seed with its own pollen, even though it came from a different head. Here was a dilemma; there was, so far as we could tell, only one plant of the red sunflower in the world, and this could not be self-fertilized! The only thing to do was to make crosses with ordinary sunflowers, and see what would come of it. It must now be explained that, aside from the color of the rays, there are many kinds of sunflowers. Putting aside the perennial species and annuals like the small "cucumber-leafed" *Helianthus debilis,* there are several types closely related to the "common or garden" sunflower, *Helianthus annuus.* All are called *Helianthus,* which is simply Greek for sunflower. The red sunflower found at Boulder belongs to the prairie species, called by some botanists *Helianthus lenticularis,* by others simply a variety of *Helianthus annuus.* It is perfectly fertile with the garden strains of *annuus,* but has a number of marked characteristics. Less robust than the cultivated forms, it branches very freely and produces numerous relatively small heads of flowers. The center, or disc, which is yellow in the big "Russian" sunflower, is "black," or strictly speaking a dark purplish-red.

The red sunflower was crossed with the Russian, the wild *lenticularis,* and with a plant which we took to be a cross, Russian and *lenticularis.* All the crosses were made by Mrs. Cockerell, who has in fact done all the work on the red sunflower. The accompanying illustration shows some of the heads covered with bags to protect them from the bees and birds and save the seeds. Crosses could be made either way, that is, using "red" pollen on the other sorts, or other pollen on the red. It was necessary in each case to "bag" the head before it came into flower, and to watch very carefully whenever the bags were off for pollination or inspection. The bees are tireless in visiting sunflowers, and scarcely a moment seems to pass during the warm part of the day when an unprotected head is not visited. A single bee might easily spoil an experiment by bringing unaccounted-for pollen, while later small finches were present in flocks to eat the seeds. All this work was time-consuming and laborious, but there is no other way if exact results are desired. Taking the principal characters, as cited above, we may tabulate the two main crosses as follows. The name *coronatus,* now used for the red sunflower, was proposed in *Science,* 1910, and was suggested by a certain resemblance to the sun in eclipse, showing the corona. The sign × signifies a cross.

(1) CORONATUS	×	LENTICULARIS
Red rays	×	yellow rays
Dark disc	×	dark disc

Branched habit	×	branched habit
Small heads	×	small heads
(2) CORONATUS	×	ANNUUS ("Russian")
Red rays	×	yellow rays
Dark disc	×	yellow disc
Branched habit	×	unbranched habit
Small heads	×	large heads.

We later found a plant of *lenticularis* showing a little red on the rays, and of course used this in a cross.

Could we predict the result of these crosses? Yes, to some extent. Could we regain the red as it was before the cross? Yes, no doubt, but in order to explain how, it is necessary to digress.

During the sixties, Gregor Mendel, Prälat at Brünn in Moravia, experimented with plants, especially garden peas. He was the first to appreciate the necessity of following up crosses for several successive generations, tabulating the results in each case, and ascertaining the numerical proportions of the differing forms resulting. He also took pains to consider the different sets of characters separately, treating them statistically as if they were different organisms. Working in this way, Mendel discovered that when two varieties are crossed the resulting hybrid is frequently not intermediate, but resembles one or the other parent. In other cases, when the hybrid, as a whole, seems intermediate, the several *characters* are nevertheless found to correspond with those of one or the other parent. When this sort of thing occurs, the character which comes uppermost in the cross is said to be *dominant,* the one which remains latent or hidden is called *recessive.*[1] Inasmuch as fertilization results from the fusion of the germ-cells of the two parents, it is evident that each individual hybrid must contain material derived from both, although only the characters of one parent may be visible. Now Mendel found that when hybrids obtained as described were crossed together in the next generation he got, in simple cases, three of the "dominant" type to one of the "recessive." Of course the proportions would not be always thus, but whenever the number of cases was large they approximated so closely to the three-to-one ratio, that he became convinced that this was no accident. A simple theory was formulated, according to which the results arose from the chance combination of the elements in the germ cells. We may now make this clearer by a diagram in which D stands for the character which is dominant, R for that which is recessive.

First cross, DD × RR

[1] The matter is complicated by the fact that the "recessive" condition may result from the simple absence of the dominant factor; or one factor, when present, may inhibit or else hide a second. For the latter class of cases the terms epistatic and hypostatic have been proposed by Bateson.

This is written DD and RR, not simply D and R, because we are supposing that each individual is pure for the character involved, that is, has received D or R from each parent.

First filial generation DR × DR × DR × DR, as many as there may happen to be. These are written DR because each gets D from one parent (which has nothing else to give) and of course R from the other. Now in the next generation each parent contributes, not its whole "DR," but one or the other, according to the laws of chance. Accordingly, DR × DR may produce a DD, or a DR, or a RR, and as a matter of fact, they do so. Why should there be any particular numerical proportion? If we put black and white balls in a bag, and draw them out in pairs at random, the chances are equal that we shall get two alike, or two different. It is so with our crosses. The cases in which we get two alike may be of two kinds, both black or both white, or in the case of the crosses, both D or both R. The cases in which we get two different are necessarily alike, black and white, or D with R. Hence, according to the law of chance, we expect in the third generation the following:

1. Both alike, DD and RR.
2. Not alike, DR and RD, which are the same.

Now we have seen that because of dominance R does not show when D is present, so that a DR looks like a DD. Consequently, of the above four cases, *three* show the dominant character, and *one* (RR) shows the recessive. The whole diagram may now be reconstructed:

1. DD × RR (original cross).
2. DR × DR × DR × DR (first filial generation).
3. DD × DR × RD × RR (second filial generation, or grandchildren). How can this be confirmed? Obviously, if the facts are as here given, the DD and the RR of the third line are now *pure,* in spite of the fact that the DD had an RR grandparent and a DR parent, and the RR a similarly complicated ancestry. Take a number of these pure types, now called "extracted recessives" and "extracted dominants," and breed them separately, the DDs with DDs, and the RRs with RRs, and they *will breed true,* and their descendents will forever remain true, unless contaminated by a cross, or some new variation arises. The DRs, however, when bred together, will again produce the "three-to-one" results, just like their parents. Consequently, it is possible to extract a pure strain out of an impure one, a fact of tremendous scientific and practical importance.

Mendel's results were published in Brünn in 1866, but attracted little or no attention. They never became known to Darwin, who would have immediately perceived their importance. In 1884, when Mendel died, no one had the slightest idea that his name would ever be familiar to scientific workers, though Mendel himself used to say "Meine Zeit

SUNFLOWER GARDEN SHOWING HEADS WITH BAGS.

wird schon kommen!" In 1900 three European workers almost simultaneously discovered Mendel's paper, and to-day "Mendelism" is talked of everywhere, and books are written upon it.

Mendel himself could hardly have foreseen the wide application of his theory. It has been applied to animals and plants with like success, and scarcely a month passes without the publication of new "Mendelian results." In practical breeding, it has opened up a new era, and

it would be difficult to overestimate the importance of the results certain to be obtained within the next fifty years. It has even been found that Mendel's discovery lights up the way toward the improvement of the human race, and it may well be that many of us now living will see the day when Mendelian questions will enter the field of practical politics.

As experimental work progressed, it was found that many complications arose, so that it was often difficult to interpret the results. Without going into these matters in detail, we must note that frequently the first cross "DR" is not like either parent, that is to say, dominance is not complete. Indeed, experienced breeders say that they can

RED SUNFLOWER.

nearly always tell an impure form from a pure individual, although at first sight they may look alike. Critics of Mendelism were at first inclined to think that the failure of strict "dominance" invalidated the theory, but this is by no means the case, as the elements separate out in the third generation, just as before. The only difference is that as one can tell the DD from the DR, in the third generation we have *three* visible types instead of two, in the proportions 1, 1, 2.

Now to return to the sunflower: the first thing we were anxious to know was, will the red be dominant? From analogy with other cases, we thought it would. Being impatient, we obtained permission from our friend Mr. Knudsen to grow a few plants during the winter of

1910–11 in his greenhouse. They grew to enormous size (being the Russian × *coronatus* cross), but when at length they flowered, *all the rays were pure yellow!* This was indeed disappointing, though we thought we could readily get the red back in the next generation. In the meanwhile, the greater part of the seed was sown in our garden, though some was sent to the English naturalist Dr. A. R. Wallace, who successfully raised the plants. During the summer we went east, but before we left, we noted with hope that some of the young plants showed a great deal of purple in the stems. On our return early in August, a gorgeous sight met our eyes. The sunflowers were in full bloom, and about half were splendidly red! The reds were by no means uniform, as the accompanying figure shows, some having a ring of red, while others were suffused with red all over, and others showed only a little of the color. Indeed on a single plant there is great variation, and often heads on a genuinely "red" plant may have wholly yellow rays. This results from the fact that the red is produced as the end-result of a chemical process, which seems to be completed only under favorable conditions. Thus a "yellow" head on a red plant differs fundamentally from a true yellow in its make-up, but resembles it, owing to what may be called a lack of opportunity. The controlling factors are not well understood, but even in the case of the original plant, the last small heads of the season were almost entirely yellow-rayed.

I have said that about half of our sunflowers were of the red type. It was a matter of chance that the four grown in the greenhouse were all yellow. But how can we reconcile these results with Mendel's law? *All* were crossed with red: if red is dominant, then *all* should be red; if it is recessive, *none* should. The explanation is, no doubt, that the original plant was a DR, not a DD. This could come about without the existence of earlier red plants, by a variation occurring in a germ-cell, which mated, of course, with one which was normal. Consequently, the original plant, though it may have had no red parent, was in fact a hybrid (or more correctly, mongrel), and *we have not yet seen a "pure" red.*

The accompanying diagram represents the supposed course of events. The first line (1910) shows the original cross made by us. When YY meets RY, two combinations are possible, and are equally probable, namely, YY (yellow) and RY (red). The result observed in 1911 thus follows naturally. The third line shows what may be obtained in 1912. If the yellows are mated, we get only yellows. We have a few of these already in bud, from seed gathered from the greenhouse plants. If we cross the reds with reds (as has been done in large numbers) we must expect one fourth pure yellows, one half impure reds like the parents (I have drawn only one to save space), and one fourth "pure" reds.

I have drawn the "pure" red very dark, on the supposition that it will be visibly more highly colored than anything yet seen, although this may not prove to be the case. If it is distinguishable, we shall then permanently isolate the red without further trouble; if it is no different from the impure reds, it will only be possible to separate the pure strain by noting the results of numerous crosses made at random.

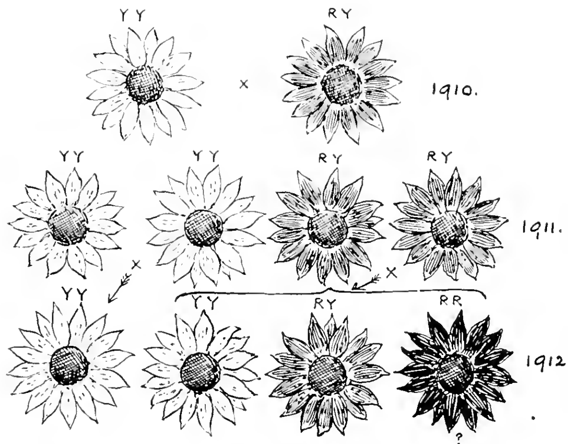


DIAGRAM SHOWING THE FIRST CROSS MADE WITH THE RED SUNFLOWER, the result obtained in 1911 and the expected result for 1912. Y = yellow-ray factor; R = red-ray factor.

Last year we made various new crosses, especially with the great double "chrysanthemum-flowered" variety obtained from Dreer of Philadelphia. If we can get this red, as we doubtless can, it will be a striking plant, though perhaps less attractive than the single kinds. In tabulating the characters crossed, I enumerated not only the ray color, but also the color of the disc, the size of the heads, and the manner of growth. In the *coronatus* × *lenticularis* cross, everything except ray color is the same on both sides, so there is nothing to be noted. In the *coronatus* × Russian cross, it is quite otherwise. We find that dark disc is uniformly dominant over yellow; the size of the heads in the cross is greater that that of *lenticularis,* but much less than that of the Russian; and the manner of growth is intermediate, at first simple like the Russian, but eventually branching at the top. It is evident that there is some correlation between the manner of growth and the size of the heads, as a plant could not well support more than one big head of the Russian type. A certain incompatibility between the two varieties seems to be indicated by a number of monstrous (fasciated) plants.

The accompanying diagram shows the Russian *coronatus* cross in relation to growth form, and in the third line the expected outcome in 1912.

In Dreer's Catalogue of 1911 appears the following:

The Red Sunflower, *Helianthus cucumerifolius purpureus.* A red annual sunflower has long been looked for, and this new hybrid strain seems to be the forerunner of a really bright red variety, containing as it does a large range of colors, from light pink to deep purplish red.

This is a garden variety of the small *Helianthus debilis,* which we understand originated in Italy. We purchased seed, which produced good plants, but showing hardly any red, and that of a dingy color. We hear from others that this variety has been a great disappointment, but are told that the originator is still working on it. In any event, it is an entirely different plant from ours.

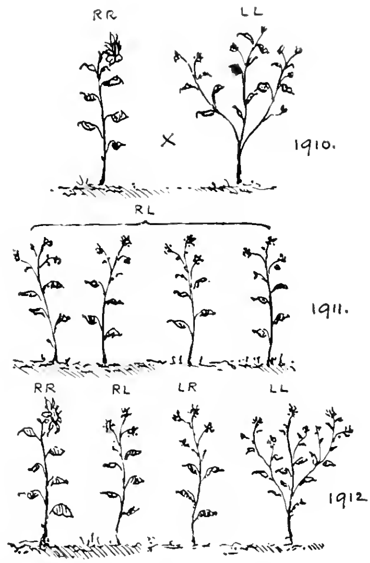


DIAGRAM SHOWING THE CROSS RUSSIAN AND RED SUNFLOWER, the manner of growth of the progeny in 1911 and the expected result for 1912.

A famous discovery somewhat parallel to that of the red sunflower is that of the Shirley poppy, which is described in Bailey's "Cyclopedia of American Horticulture" as "the loveliest of all poppies" and "one of the finest contributions to floriculture ever made by an amateur." The Rev. W. Wilks, of Shirley in England, gives the following account of his discovery and development of this poppy. This was written without any knowledge of Mendelism, and can not at once be reduced to Mendelian terms. It is evident, however, that the Shirley is a *minus* variation (loss of black pigment), and may be expected to behave as a recessive.

In 1880, I noticed in a waste corner of my garden, abutting on the fields, in a patch of the common wild field poppy (*Papaver rhœas*), one solitary flower the petals of which had a very narrow edge of white. This one flower I marked, and saved the seed of it alone. Next year, out of perhaps two hundred plants, I had four or five on which all the flowers were edged. The best of these were marked and the seed saved, and so on for several years, the flowers all the while getting a larger infusion of white to tone down the red, until they arrived at a quite pale pink, and one plant absolutely pure white. I then set myself to change the black central portions of the flowers, from black to yellow or white, and at last fixed a strain with petals varying in color from the brightest scarlet to pure white, with all shades of pink between, and all varieties of flakes and edged flowers also, but all having yellow or white stamens, anthers and pollen, and a white base. . . . My ideal is to get a yellow *Papaver rhœas,* and I have already obtained many distinct shades of salmon. The Shirley poppies have thus been obtained simply by selection and elimination. . . . Let it be noticed that true Shirley poppies (1) are single, (2) always have a white base, with (3)

yellow or white stamens, anthers and pollen, (4) never have the smallest particle of black about them. . . . It is rather interesting to reflect that the gardens of the whole world—rich man's and poor man's alike—are to-day furnished with poppies which are the direct descendents of one single capsule of seed raised in the garden of the Shirley Vicarage so lately as August, 1880.

It is certain that many more good variations would be discovered if trained people were everywhere on the lookout for them, and it must be remembered that among the cereals, for example, a good new strain will not be a conspicuous object like a red sunflower. There is here a fascinating field for amateurs, with possibilities of vastly increasing the wealth of mankind, or adding beauty to his gardens. Aside, however, from the discovery of new things, there is an almost unlimited field open for the crossing of known varieties, and their recombination along Mendelian lines. Any one who has a garden may do this work, and if nothing else comes of it, it will certainly give much pleasure and an insight into some of the most interesting biological problems of the day.

THE MEDICAL SIDE OF IMMIGRATION

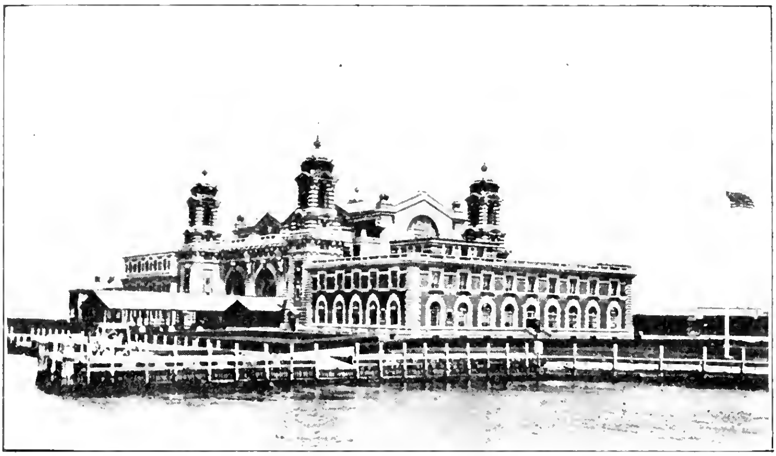
BY DR. ALFRED C. REED
ASSISTANT SURGEON, U. S. PUBLIC HEALTH AND MARINE HOSPITAL SERVICE
NEW YORK CITY

PERHAPS no question is of more paramount and continuing interest to the American people than immigration in all its phases and relations to public welfare. The history of the United States is the history of alien immigration. The earliest pioneers were themselves alien immigrants. Our institutions, political, religious and social, have been founded and supported by aliens or their near descendants. Our country is indeed a melting-pot, into which have been poured diverse varieties of peoples, from all nations and races. Yet in the face of this, these variant elements have been fused into a more or less homogeneous nation. A national life and character we have. This national or American character is not exemplified in those places where the large streams of immigration are pouring in, but farther away where the waters have mixed. Such a condition, unique in the history of nations, is responsible for certain problems which are also unique in history, and consequently do not admit of solution according to precedents.

The first rule of national life is self-preservation, and since immigration has had and still has so important a rôle in American national life, it must be carefully scrutinized to determine which immigrants are desirable, and *vice versa,* from the standpoint of the betterment and continuance of the American nation. The choice between free immigration, restricted immigration, and absolute exclusion is increasingly difficult to make, and does not enter our field of inquiry, except to recall a principle which is as valid from the medical standpoint as from the economic or social. Only those peoples should be admitted whom experience has shown will amalgamate quickly and become genuine citizens. The period of residence necessary for citizenship should be raised from three to five years, during which time the immigrant should be literally on probation, and subject to deportation if found wanting, or if unable to meet the qualifications of citizenship at the end of that time. The government should decide where the immigrant may settle and the immigration current should be directed to the western and farming districts, and not allowed to stagnate in eastern cities.

The great mass of popular literature on the subject of immigration is singularly deficient in discussion and analysis of its medical features. It is true, the United States government bestows on public health and preventive medicine no where near the attention it finds necessary for the prevention of disease in stock and for agricultural improvement, but

none the less there are certain well-organized and efficiently operated agencies which have for their function the improvement of public hygiene and sanitation, the eradication of preventable disease, and the study of causation and methods of control of diseases. Most of these functions are exercised by the Public Health and Marine Hospital Service, which, strangely enough, constitutes a bureau under the Treasury Department. Some of this work is done under the Department of Agriculture, and other minor lines are scattered elsewhere through the national machinery. It is easily seen how much more efficient would be the work were all these agencies for national health protection united



THE IMMIGRATION STATION, ELLIS ISLAND.

under one administrative head, and their various activities carefully coordinated.

The Public Health and Marine Hospital Service operates all national quarantine stations where inspection is made for yellow fever, typhus fever, smallpox, bubonic plague, leprosy and cholera; maintains hospitals throughout the country for sailors of the American merchant marine; conducts the Hygienic Laboratory at Washington for the study of the causation and treatment of diseases; exercises numerous minor functions of a national board of health; and conducts the medical inspection of immigrants. Certain diseases are found so frequently among immigrants, and others are so inherently dangerous, as to merit special mention because of their important relation to public health.

First among these might be placed trachoma, a disease of the eyelids characterized by extreme resistance to treatment, very chronic course and most serious results. Most of the immigrant cases occur in Russians, Austrians and Italians, although it is of common occurrence in oriental and Mediterranean countries. It causes a large percentage of

the blindness in Syria and Egypt. Its contagious nature, together with the resulting scarring of the lids and blindness, make its recognition imperative. The hookworm (*Uncinaria*) has received much attention lately since it has been found so widely distributed through the mountains of the south, the mines of California, the middle west, etc. It is a minute parasitic intestinal worm about three fifths of an inch long, and under the microscope shows relatively enormous and powerful chitinous jaws by means of which it attaches itself to the intestinal walls. The saliva of the hookworm has the curious property of preventing coagulation of blood like leech extract, and when it is remembered that the worms may vary in number from several hundred to a thousand or more, and that each worm moves frequently from place to place on the intestinal wall, it is apparent how excessive and continuous is the drain on the blood and lymph juices. The result is an extreme anemia which brings in its wake a varied multitude of bodily ills, and may eventuate fatally, meanwhile having incapacitated the victim for mental or physical work. Infection can spread rapidly from a single case. Not many hookworm carriers have been discovered among immigrants, probably because the facilities for their detection are so meager. But the heavy immigration from countries where uncinaria is abundant, as well as the recent suggestive work of Dr. H. M. Manning at the Ellis Island Immigrant Hospital, indicate that there is a constant stream of fresh infection pouring in. Indisputably routine examination for hookworms should be instituted. The same can be said of other intestinal parasites as tapeworms, pin worms, whip worms, eel worms and others. One of the tapeworms, the so-called fish worm (*Dibothriocephalus latus*) leads to an anemia fully as severe as that from the hookworm.

Many other diseases might be mentioned, but these are sufficient to illustrate the importance of careful medical inspection of immigrants.

The total immigration into the United States through all ports of entry for the year ending June 30, 1911, was 1,052,649. Of these 22,349 were debarred for various reasons, leaving a net increase of 1,030,300. The chief port of entry is, of course, New York, where 749,642 aliens were examined. Next in order of importance come Boston, Baltimore and Philadelphia, and at a greater distance Galveston, Tampa, San Francisco, Honolulu, Miami and Portland, Me. As the laws are uniform and the methods of inspection the same at all ports, consideration of methods and results at Ellis Island, N. Y., will give a clear idea of the entire subject.

The medical inspecting service at Ellis Island is divided into three branches, the hospital, the boarding division and the line. The hospital division presents an excellently equipped and managed institution, and an isolated set of buildings for contagious diseases. The hospital service is limited exclusively to immigrants, and the patients are those acutely ill upon arrival, those taken sick during their stay on the island,

LANDING FROM BARGE AT ELLIS ISLAND.

and cases of acute sickness among aliens already landed who for some reason have been brought to the island for deportation.

The boarding division of the medical inspection on Ellis Island has for its particular function the inspection of aliens in the first and second cabins on board the incoming vessels. Those who require more detailed examination are sent to Ellis Island.

The routine inspection on the line is that part which the visitor sees, and is the most important feature of the medical sieve spread to sift out the physically and mentally defective. The incoming immigrants pass in single file down two lines. Each of these lines makes a right-angled turn midway in its course. At this turn stands a medical officer. He sees each person directly from the front as he approaches, and his glance travels rapidly from feet to head. In this rapid glance he notes the gait, attitude, presence of flat feet, lameness, stiffness at ankle, knee, or hip, malformations of the body, observes the neck for goitre, muscular development, scars, enlarged glands, texture of skin, and finally as the immigrant comes up face to face, the examiner notes abnormalities of the features, eruptions, scars, paralysis, expression, etc. As the immigrant turns, in following the line, the examiner has a side view, noting the ears, scalp, side of neck, examining the hands for deformity or paralysis, and if anything about the individual seems suspicious, he is asked several questions. It is surprising how often a mental aberration will show itself in the reaction of the person to an unexpected question. As the immigrant passes on, the examiner has a rear view which may reveal spinal deformity or lameness. In case any positive or suspicious evi-

dence of defect is observed, the immigrant receives a chalk mark indicating the nature of the suspicious circumstance.

At the end of each line stands a second medical officer who does nothing but inspect eyes. He everts the eyelids of every person passing the line, looking for signs of trachoma, and also notes the presence of cataract, blindness, defective vision, acute conditions requiring hospital care and any other abnormalities. All cases which have been marked on the line are separated from the others and sent to the medical examining rooms for careful examination and diagnosis. When it is remembered that often 5,000 immigrants pass in a day, it is clear that the medical officers not only are kept busy, but that they see an unusually wide variety of cases.

After careful examination, the nature of the defect or disease found, is put in the form of a medical certificate which must be signed by at least three of the physicians on duty. It is not within the province of the medical officers to pass judgment on the eligibility of the immigrant for admission. The medical certificate merely states the diagnosis, leaving to the immigration inspector in the registry division the duty of deciding the question of admission. In the inspector's consideration are included not alone the medical report, but all other data concerning the applicant, such as age, money in his possession, previous record, liability to become a public charge, and his sponsors.

Most cases of trachoma and mental or organic nervous disease are sent to the hospital and kept under care and observation to facilitate an accurate diagnosis. Seldom indeed does the alien suffer from too harsh a medical judgment. He is given the benefit of a doubt always. For example, if a case of defective vision is found to be 3/20 normal, it would be certified as perhaps 5/20 normal.

The immigration law as it stands since the legislation of 1907, divides all defective immigrants into the following classes: Class A, aliens whose exclusion is mandatory because of a definite and specified

LINED UP, WAITING FOR THE MEDICAL EXAMINATION.

defect or disease. Class B, aliens not under class A, but who possess some defect or disease which is likely to interfere with the ability to earn a living. Class C, aliens who present a defect or disease of still lesser seriousness, not affecting ability to earn a living, but which none the less must be certified for the information of the immigration inspectors.

Under class A, the excluded, are listed idiots, imbeciles, the feeble-minded, the epileptics, the insane, persons afflicted with tuberculosis of the respiratory, intestinal or genito-urinary tracts, and loathsome or dangerous contagious diseases. By contagious the law means communi-

A Cosmopolitan Group on the Roof of the Detention Quarters.

cable. Loathsome contagious diseases include those whose presence excites abhorrence in others, and which are essentially chronic, such as favus, ringworm of the scalp, parasitic fungus diseases, Madura foot, leprosy and venereal disease. Dangerous contagious diseases are such as trachoma, filariasis, hookworm infection, amœbic dysentery, and endemic hematuria.

Under class B, diseases and defects not in class A but which affect ability to earn a living, are such conditions as hernia, organic heart disease, permanently defective nutrition and muscular or skeletal development, many deformities, varicosities of the lower extremities, premature senescence and arterial degeneration, certain nervous diseases, chronic joint inflammations, poor vision and tuberculosis of the bones, skin or glands. The immigration law makes no distinction between

cabin and steerage aliens, and the medical officer has no duty beyond the purely medical inspection.

Commissioner of Immigration Williams for the Port of New York in his recent report[1] for the fiscal year ending June 30, 1911, makes some pertinent observations and recommendations regarding the medical phases of the immigration question at Ellis Island. He finds that the present medical quarters are not large enough for the proper execution of the laws relating to physical and mental defectives. Expansion to an appropriate size is prevented by the failure of Congress to appropriate the funds requested. He notes the large number of feeble-minded children in the schools of New York City who have passed Ellis Island, and gives as one reason, lack of time and facilities for thorough examination as to mental condition. The result is that the law in this particular is practically a dead letter. According to the law, the feeble-minded as well as idiots and imbeciles are absolutely excluded. It is of vast import that the feeble-minded be detected, not alone because they are predisposed to become public charges, but because they and their offspring contribute so largely to the criminal element. All grades of moral, physical and social degeneracy appear in their descendants, and it is apparent how grave is the social and economic problem involved. The steamship companies do not exercise proper precautions in receiving immigrants for passage, and this makes all the more necessary a rigid inspection at the port of entry into this country.

The report of the Chief Medical Officer on Ellis Island, Dr. G. W. Stoner,[2] shows that during the year ending June 30, 1911, nearly 17,000 aliens were certified for physical or mental defect and over 5,000 of these were deported (not necessarily for medical reasons alone). Among those certified were 209 mental defectives, of whom 45 per cent. were feeble-minded, and 33 per cent. insane. Under loathsome and dangerous contagious diseases there were 1,361 cases, of which 85 per cent. were trachoma. Over 11,000 aliens had a defect or diseases affecting ability to earn a living and half of these were due to age and the changes incident to senescence. More than 4,000 certificates were rendered for conditions not affecting ability to earn a living.

Over 6,000 aliens were treated in the immigrant hospital, beside 720 cases of contagious disease, which were transferred to the State Quarantine Hospital at the harbor entrance before the completion of the present contagious-disease hospital on Ellis Island. Among these 700 there were a hundred deaths, chiefly from measles, scarlet fever and meningitis. The medical officers also examined 168 cases which had become public charges in surrounding towns of New York, New Jersey

[1] Williams, Wm., Commissioner of Immigration for Port of New York, Annual Report for year ending June 30, 1911.

[2] Stoner, G. W., M.D., Chief Medical Officer, Ellis Island, Annual Report for year ending June 30, 1911.

FROM HOLLAND.

and Connecticut to determine the nature of the illness and if due to causes existing prior to landing. Chief among the contagious diseases were measles, chicken-pox, diphtheria and scarlet fever. The quarantinable diseases, cholera, leprosy, bubonic plague, smallpox, typhus and yellow fever are removed at the New York Quarantine Station before the vessels are docked.

Statistics such as these inevitably suggest a brief consideration of the different sources of immigration and their relative desirability from the medical standpoint. In general it may be said that the best class is drawn from northern and western Europe, and the poorest from the Mediterranean countries and western Asia. Among the worst are the Greeks, South Italians and the Syrians, who emigrate in large numbers. The Greeks offer a sad contrast to their ancient progenitors, as poor physical development is the rule among those who reach Ellis Island, and they have above their share of other defects.

The old question of the desirability of the Hebrew must be settled on other grounds than those of physical fitness alone, although even here the medical evidence is decidedly against him, as Dr. McLaughlin[3] has shown that the proportion of defectives to total landed is greatest among the Syrians, 1 in 29, and next greatest among Hebrews, 1 in 42. Contrary to popular belief, the Jewish race is far from a pure stock, and has been colored by various and repeated admixtures with other bloods. Hence Jews of different nationalities differ considerably in their physical status and aptitude for American institutions, and for amalgamation

[3] McLaughlin, THE POPULAR SCIENCE MONTHLY, Vol. 62, p. 234.

with our body politic. No race is desirable which does not tend to lose its distinctive traits in the process of blending with our own social body. It would seem from history that the Jew only blends inadvertently and against his conscious endeavor and desire. Hence the process of true assimilation must be very backward. Moreover, in origin, racial traits, instincts and point of view, the Hebrew race is essentially oriental, and altogether there is at least ground for objection to unrestricted Jewish immigration.

No one can mistake the pressing necessity for a solution of the immigration problem. The problem of New York City in this respect is unique and differs from that of the rest of the country, because as Walter Laidlaw[4] points out, New York City is in reality a foreign city, inasmuch as in 1910 the native-born of native parents numbered only 193 in every 1,000 inhabitants. This preponderating foreign element is due to the concentration of arrested immigration in New York. For the country as a whole, great interest attaches to the influence which the Panama Canal will exert in diverting immigration lines to southern and Pacific coast points. New local problems will of course arise, but the basic proposition remains always the same. Immigration should be restricted absolutely to such races as will amalgamate, without lowering the standard of our own national life.

In general, immigrants from the Mediterranean countries should be excluded, especially those from Greece, South Italy and Syria, as well as most Hebrews, Magyars, Armenians and Turks. Strict enforcement

NEGROES FROM THE WEST INDIES.

[4] Laidlaw, Walter, *New York Times,* December, 1911.

of the present medical laws will automatically exclude these races to a sufficient extent, admitting the few who are fit. This, combined with a strictly enforced five-year probation period, with deportation as the penalty for any criminal conviction or for failure to qualify for citizenship afterward, would go far toward relieving the situation. This need not disqualify aliens from travel in the United States.

The immigrant per se has no moral or social right to enter this country against the will of its citizens. An enduring commonwealth must of necessity guard rigidly the health of its citizens and protect itself against undesirable additions from without. There was a time when European immigration was free, and almost entirely of desirable classes. That time has passed. The less desirable classes are increasing actually and relatively, and at the expense of the more desirable. It can truthfully be said that the dregs and off-scourings of foreign lands, the undesirables of whom their own nations are only too eager to purge themselves, come in hosts to our shores. The policy of those advocating free immigration would make this country in effect the dumping ground of the world.

Exclusion of these undesirables works no injustice to the lands from which they come. A large emigration from a land usually is followed by an increased birth-rate, and the net change is slightly affected, if at all.[5] Admitting undesirables to this country will in no wise elevate the world's human standard, because those undesirables will multiply as fast here as in their original home, and their stock will only become extinct when it ceases to perpetuate itself. High requirements for admission to this country reflexly raise standards of living and education in those lands from which our immigrants are drawn. This was illustrated in Italy[5] a few years ago when the higher requirements for admission caused an enforcement of the primary education laws which were dead letters before. Again, increase of a poorer class of immigration decreases the number of the better class and also decreases the chances of those who do come.

The medical phases of immigration blend very quickly into the subjects of national health protection, national eugenics and even the future existence of the ideals and standard of life which we are proud to call American. Conservatism and a carefully maintained medium between absolute exclusion, and free immigration, certainly seems the best policy.

[5] Hall, Prescott, F., "Eugenics, Ethics and Immigration."

ANCIENT PORTALS OF THE EARTH

By Professor JAMES PERRIN SMITH

STANFORD UNIVERSITY, CALIFORNIA

Portals Defined.—A study of the distribution and relationships of ancient marine faunas shows that there have been certain critical areas through which these faunas were connected from time to time. These critical areas are depressions on or between continental masses, and are invariably regions of permanent instability of the earth's crust, where mountain-making and the accompanying volcanic and earthquake disturbances have been prevalent.

When these areas were depressed below sea-level, they formed straits, or channels, connecting sea-basins, and affording avenues for inter-migration of marine faunas. When they were elevated, they formed barriers impassable to the dwellers in the sea. Thus neither the name strait nor barrier is applicable to them as a general term. Therefore the name *portal* is selected, as indicating a gateway that may be either open or closed, and still retain its identity.

Of the portals that were important in the ancient world only three are now open: the North Pacific portal, of which Bering Strait is a shrunken remnant; the Iberian, still recognizable in the Strait of Gibraltar; the Malaysian, seen in the inter-island passages in the East Indian Archipelago. And one has shifted its position, growing from an arm of the sea into the noble expanse of the Indian Ocean.

One still shows its nature as a portal in the narrow strip of land joining the two Americas. The others are now concealed as parts of continental masses, namely the Crimean, the Asia Minor portal, and the Bokharan, revealing their nature as former arms of the sea only in the extinct marine fossils now buried in their sediments.

Still other bodies of water that loom up large in our present-day geography, as the North Atlantic and the South Atlantic, too wide to be called merely passages, or to be differentiated from the main ocean by a special name, did not even exist in the ancient days.

These great changes have been wrought chiefly by the world-wide Tertiary mountain building, and the accompanying, or causing, disturbances of the continental areas. Also there was much readjustment in the late Paleozoic topographic revolution, and in the late Jurassic Cordilleran revolution.

Paleogeography.—In recent years the reconstruction of ancient physical geography has been a favorite field of research, not to say of speculation, of geologists; paleontologists, too, have taken their part in

this, since ancient continents can be outlined only by the distribution of the faunas and floras of the land, and ancient seas can be traced only in the remains of petrified inhabitants of the waters.

In the Book of Genesis we read: "And God said, Let the waters under the heaven be gathered together into one place, and let the dry land appear; and it was so. And God called the dry land Earth; and the gathering together of the waters called He seas: and God saw that it was good." This is certainly the shortest account of the origin of continents and seas, and probably as good as any. But we do not any longer think that it all happened at one time.

Since we can know definitely the geology of only that part of the earth which is now land, and since we know the underlying strata of only a small part of that, we can only conjecture concerning the history of regions now buried under the oceans. No one man, nor group of men, is qualified to make a dogmatic statement as to the origin of continents and seas, such as that quoted above from Holy Writ. There is ample room for differences of opinion, starting from the same facts. Consequently, geologists and physical geographers are divided into two camps. One holds that the major divisions of land and sea were always as they now are; this is the doctrine of permanence of continental plateaus and oceanic basins. The other group advocates the idea of constant change in the position of land masses and oceanic troughs. To them the grand features of the earth do not bear the marks of hoary antiquity, but are youthful characters, due to rather modern diastrophism of the crust.

The truth probably lies somewhere between the two extremes, and the differences between the two camps consist rather in statement than in fundamental doctrine. Even the most conservative upholders of the theory of permanence admit that some of the continental areas have been covered, in the past, by seas of almost oceanic size and depth. And the most radical advocates of the shifting of lands and seas believe that some of the continental masses have always been continents, and that some of the great depressions have always been oceans.

Further, it becomes plainer, as paleogeographic studies go deeper into the history of the earth, that the dominant ancient features are not obliterated by later changes, but are merely obscured. Continents that were dismembered have been united again; seas that existed in the early days have recurred. Which is to say that whether continental plateaux and oceanic troughs have been permanent or not, the regions of diastrophism have been permanent, that when crumpling and dislocation of the earth's crust have once started, they have kept up with recurrent activity all through the succeeding ages.

The ancient portals all lie in regions where the Tertiary mountain folds touch the great lines of crumpling begun in the late Paleozoic topographic revolution. The present distribution of continental pla-

teaus and oceanic troughs dates from the Permo-Carboniferous revolution, although the North Atlantic and the South Atlantic were not occupied by the sea until early Tertiary time.

During Cambrian time the Bering, Central American, Iberian, and Asia Minor portals were open, probably corresponding to regions of Pre-Cambrian folding. The others had not yet come into existence, or at any rate information is lacking concerning them. In the Lower Silurian we know of the existence of the Bering portal. During the Devonian the Bering and the Asia Minor portals were open all the time, the Crimean part of the time, while the Bokharan portal was merely part of the open Asiatic sea. During the Carboniferous era all the major portals were open at times except that leading down to Madagascar. Somewhere near the border between Coal Measures and Permian the Paleozoic topographic revolution inaugurated centers of distribution and portals connecting them that held sway during nearly the whole of Mesozoic time.

If diastrophism should be the final arbiter of the division of geological time, then on the basis of physiography the Permian, including the Artinsk stage, should be included in the Mesozoic. For while Permian life is distinctly more closely related to that of the Paleozoic, Permian physiography is like that of the Triassic.

Interregional Faunal Zones.—It is customary to speak of cosmopolitan faunas in the past ages, but this term is properly applicable only to the Cambrian and Silurian, when local differentiation had not yet caused the extremes of later times. And even in the Cambrian, as the scanty faunas become better known, provincial differences appear.

In Devonian time provincial distinctions were already well developed, and the invasion of a region by an exotic fauna is easily recognized. The first interregional migration that is definitely known occurred early in the Upper Devonian, when the American waters were invaded by a fauna that could not have sprung from its predecessors in that region, but was endemic in Eurasia. This is the zone of the *Cuboides* fauna, which was followed by still further immigration from the same center of dispersion, in the zone of *Manticoceras intumescens* of the Upper Devonian. The connection with Europe was through the back door, through northern Siberia, across North America, for the continental mass of North Atlantis and Appalachia prevented direct communication.

With the opening of the Carboniferous age the subsidence of the southern part of Appalachia allowed direct intermigration between the waters of western Europe and the Mississippian Sea through the Poseidon basin. Here we find the faunal zone of *Aganides rotatorius* common to the two regions, but unknown anywhere else. This is the first direct invasion of the American seas by a population from the western Tethys, or ancient Mediterranean basin. In the latter part of

the Lower Carboniferous epoch another migration from western Europe to the Mississippi basin took place; this was in the zone of *Goniatites striatus,* which, as was the case with the preceding zone, did not extend beyond the Mississippian Sea. At this time in the western part of North America, the Great Basin Sea was connected with northern Asia, and through that region with Europe. The Pacific region lacks the fauna of *Goniatites striatus,* but has, instead, that of *Productus giganteus.* Here, for the first time, we see a sharp differentiation into Mediterranean and Pacific types of faunas, separated by the land barrier of the Rocky Mountain area.

In the age of the Coal Measures we find further evidence of continued invasion of the Mississippian Sea by immigrants from the western European Tethys, in the faunal zone of *Gastrioceras Listeri.* This group was common in the shallow epicontinental expansion of the old Mediterranean Sea, and reached America along the shores of the Poseidon Ocean, the Paleozoic ancestor of the modern Atlantic, and into the Mississippian basin through the Gulf of Mexico, up into Arkansas, Texas, Oklahoma, Missouri, Kansas, Illinois, etc. But the western sea of the Great Basin was dominated by a fauna from the boreal waters, which came down through the Bering portal, along the old shore line of northwestern America. The Mediterranean fauna extended eastward through the Tethys to Sumatra, and up into the Ural Mountains, showing that the Iberian, the Bokharan, and the Asia Minor portals were all open. The Malaysian portal was apparently closed, and the Madagascar geosyncline as yet shows no evidence of its existence.

The Artinsk, or Permo-Carboniferous transition, fauna has approximately the same regional distribution as that of the zone of *Gastrioceras Listeri,* except that it reached further northward, to Nova Zembla. But while the Carboniferous cephalopod fauna may be considered as Mediterranean in origin, the Artinsk fauna probably came from further east; its real home seems to have been on the border between Asia and Europe, for there it is most abundantly developed, and bears the closest resemblance to its predecessors.

At this time the northern Asiatic-Pacific fauna had a different character, but is as yet little known. In America it is known in California, and in the southern embayment that stretched from the Pacific to western Texas. It is called the Guadalupian fauna, from Guadalupe Mountains in Texas, where it was first described. In Texas these two faunas, the Artinsk and the Guadalupian, come within a few hundred miles of each other. The east and the west, the Atlantic and the Pacific, were separated then, as they were during most of the Carboniferous.

On the west, the Guadalupian or Pacific fauna, penetrated the Great Basin Sea, but did not extend far inland on the continent, the high lands of Utah and Idaho still separating it from the Cordilleran extension of the Mississippi sea.

During at least a portion of the Permian the Bering portal was open, the Central American closed, the Iberian, Asia Minor, and Bokharan portals open, and the Malaysian portal closed, for the characteristic cephalopod fauna, with *Medlicottia* and its associates, occurs in Texas, Sicily, the Ural Mountains, Nova Zembla, the Himalayas, and Timor in the Indian Archipelago. The Pacific, or Guadalupian type, on the other hand, is distributed from Japan around the old Pacific shore line to California, and in another gulf across the more southerly part of the American continent to western Texas.

At the end of the Paleozoic era there was much mountain-making, and readjustment of physiography. These disturbances separated some regions that had been united, and joined others that had been divided. In the earliest epoch of the Lower Triassic, the zone of the *Meekoceras* fauna, the Asia Minor portal, through which the Artinsk fauna had migrated between the western Mediterranean and the Oriental Tethys, was closed, while the Malaysian portal into the Pacific was open. The barrier between the Atlantic and the Pacific still existed in Central America. The *Meekoceras* fauna is distributed from Spitzbergen, down to India, eastward to Timor in the Indian Archipelago, with a southward arm of the sea extending down to Madagascar, connecting with the Pacific, stretching along the Siberian coast at Wladiwostok, and then across to Idaho and California in the Great Basin Sea.

The next fauna in the Lower Triassic, that of the *Tirolites* zone, is known only in the Mediterranean Region and in Idaho, the connection being from the Mediterranean-Poseidon Ocean to the Pacific, through the Central America portal, which was temporarily opened by subsidence in that region. All the other portals were closed, so far as we have any information concerning them, this conclusion being based on the provincial character of the faunas of the seas.

In the epoch immediately following, the *Columbites* zone, is seen the same provincial, or restricted distribution of inhabitants of the seas. The *Columbites* fauna is found in Idaho, in northern Siberia, and in Albania, but not in India, nor the Oriental Tethys. At this time the Arctic Sea was the center of dispersion, and immigrants went southwestward to Albania, and southeastward to Idaho, but did not reach the Indian waters, in which a different group of inhabitants lived.

In the Middle Triassic the Asia Minor portal and that of Central America were reopened, and the *Ceratites trinodosus* fauna, with the Mediterranean as its center of dispersion, was distributed westward through the Poseidon-Atlantic to Idaho, and eastward to India. There was also some connection northward to Spitzbergen, and southward to New Zealand, for the binular genus, *Daonella,* is represented by nearly identical species in all these regions.

In the Karnic horizon zone of *Tropites subbullatus,* in the Upper Triassic, the same connections still existed, with even closer relation-

ships of widely separated faunas. A large proportion of the Karnic species of India is identical with the Mediterranean fauna, and in California about one third are common forms in the Alps and Sicily.

Immediatelly above the beds with *Tropites subbullatus* in India, the Alps, and in California occur massive limestones full of coral reefs, with some few identical species in all three regions. This same group of ancient reef-builders has also been found in Alaska, in the same stratigraphic position. This shows that the wide distribution of the Upper Triassic species was made possible by the nearly uniform distribution of warm water over a great part of the globe.

In the latter part of the Upper Triassic widespread physiographic disturbances had again divided the great zoologic regions. The Atlantic-Pacific connection had disappeared, but there was still free communication between the Alpine province and the Orient, for Mediterranean species reached as far as India and Timor. Around the North Pacific, with the Arctic sea as its center of dispersion, a different fauna, that of the bivalve, *Pseudomonotis ochotica,* was distributed. This extended from northern Siberia southwestward to the Crimea, southeastward to the Great Basin Sea, and southward along the shores of Asia through Japan to New Zealand.

In the Lower Jurassic we find a recurrence of the same conditions that prevailed in the Karnic epoch, free communication through the Central American and Asia Minor portals, and between the Pacific and the Oriental Tethys, with nearly identical species ranging from the far north to the south temperate region in Argentina, and from the Mediterranean eastward to Timor and westward to California.

In the Middle Jurassic similar geographic relations continued, with clear evidence of a warm climate from Franz Joseph Land to Madagascar and Argentina, and no division into climatic zones. Cycads flourished on the land, and corals built reefs in the seas. This was too good a state of affairs to last long in this world, and there soon came a change. The Central American portal was closed, as was that between the Pacific and the Tethys. The Arctic Sea became the center of dispersion of a boreal fauna, which made its way down to Russia on one side, and to California and Mexico on the other. This arrangement of the geographic provinces reminds us strongly of that during the Triassic epoch of *Pseudomonotis subcircularis,* and it continued into the Cretaceous period.

The Upper Cretaceous is signalized by the closing of the Bering portal, and the wide distribution of a tropical fauna from the Indian waters westward to the Mediterranean waters, and eastward through Japan, around the North Pacific shore-line to California. This same fauna was also distributed from the Mediterranean westward through the Poseidon Sea to Mexico, and southward into South America. And

a southern arm of the Oriental Tethys carried the same assemblage of forms down to South Africa.

The early Tertiary Eocene epoch witnessed the reopening of the Central American portal, and the immigration of the Mediterranean *Venericardia planicosta* fauna into the Pacific waters of the Californian province. This is the last true interregional zone in the history of the earth, and it is the last time when widespread warmth of the waters made such distribution possible. Since that time the Central American and the Asia Minor portals have been closed, and the continually increasing demarcation of climatic zones have prevented migration between the greater sea basins through northern waters. The later Tertiary epoch witnessed the inauguration of modern conditions, and the geographic regions were restricted as they are now.

PTOMAINES AND PTOMAINE POISONING

By EDWIN LE FEVRE, A.B., M.D.

THE subject of food poisoning is one that is commanding a constantly increasing attention on the part of the general public. A brief résumé therefore of the most important facts relating to ptomaines and ptomaine poisoning together with some deductions based thereon may be of interest to all who would be informed on matters relating to their physical welfare—certainly so to those who are practical conservators of the public health.

Ptomaines are chemical compounds of an alkaloidal nature formed in protein substances during the process of putrefaction. In order to a clear understanding of the subject, emphasis is to be laid on the fact that they are purely *chemical* bodies formed out of the medium in which they occur.

In this respect they are to be differentiated from the toxins, which are poisons of unknown composition, formed within the bacterial cell itself and in the case of certain organisms, given off to the medium in which they grow. They are also to be differentiated from another class of compounds known as leucomaines, which may in some instances be of like chemical composition, but which are formed only within the living body, usually as the result of tissue metamorphosis. From these, when not properly eliminated, we get the varied phases of auto-infection.

Putrefaction is the biochemical process by which all protein matter is reduced to the inorganic state from whence it came, thus completing the life cycle. This change is brought about by the action of micro-organisms. A certain group of bacteria have the power to split up the complex protein molecule and thus form new and simpler compounds. As a result of their action we have formed first albumoses and peptones and from these we have formed the amino acids which are the great foundation stones of the proteins. These are still capable of sustaining bacterial life and the splitting-up process continues. As a result we may get a large number of products, solid (crystalline), liquid and gaseous—and among them may be some of the basic compounds which we call ptomaines.

So far about sixty ptomaines have been isolated and studied and of these about one half are more or less poisonous. It is to be borne in mind that the so-called ptomaines are not a distinct class of chemical compounds, but differ widely both in chemical composition and physical characteristics. Indeed it may be said that they have only this in common, that they are basic and contain nitrogen. Some of them are comparatively simple and well-known organic compounds like the simple

amines, others are much more rare and complex; "some are strongly alkaline and basic, others but feebly so; some are liquid, oily and volatile, others fixed and crystalline; some are very prone to change, others quite stable."

Two thirds of the known ptomaines contain only carbon, hydrogen and nitrogen. These represent the simple ammonia substitution compounds. All those that contain oxygen in addition (the so-called oxygenated bases) possess the trimethylamin molecule as their basic constituent.

Gautier has probably given the best classification of the ptomaines. He divides them into the following groups:

Monamines of the fatty acid series.

Diamines of the fatty acid series.

Guanidines.

Aromatic ptomaines free from oxygen.

Oxygenated ptomaines.

Aromatic oxygenated bases.

Unfortunately the isolation of a ptomaine from any decomposed or putrid material is a very difficult matter. This is true largely because of the great number, complexity and diversity of the other substances present in the decomposing mass and the fact that these may be at varying stages of putrefaction.

Some of the ptomaines are volatile and are decomposed at any temperature near that of boiling water. Others, very prone to undergo decomposition, may be destroyed by the action of the reagents used. Hence efforts to determine their presence and character are very apt to be attended with failure. In all of these cases, however, where a sufficient amount of a suspected food can be obtained an attempt should be made to determine the presence of any decomposition products that may have been responsible for toxic symptoms. In every case the chemical analysis must be supplemented by a bacteriological examination (much more promising of results) under both aerobic and anaerobic methods to determine the character of the microorganisms present. From pure cultures thus obtained inoculations should be made in suitable animals to determine their infectious character and filtered cultures used to determine the presence of soluble toxins.

It is quite probable, as the more recent investigations have shown, that many cases of food poisoning ordinarily classed as of ptomaine origin are in reality due to a direct infection by bacteria in the food which possess pathogenic properties or to toxins formed by them. The tendency to designate all bacterial food poisoning as ptomaine poisoning is not therefore strictly in accord with the facts as we now know them.

The resemblance of the ptomaines to the vegetable alkaloids has been noted. These two groups of compounds resemble each other in

their chemical composition and to a certain extent in their physiological action. The ptomaines have sometimes been called the animal alkaloids. This, however, is misleading, as ptomianes may be formed in vegetable as well as in animal proteins. Their essential difference is to be found in their origin. The ptomaines are decomposition products and largely belong to the aliphatic series, whilst the true plant alkaloids are cyclic compounds and practically all of them pyridin derivatives. Owing to the wide variation in the chemical constitution of the ptomaines no analytical methods are known or possible by which they can be differentiated as a class from the vegetable alkaloids. This is possible in the case of certain ptomaines but not all. As a result of this it is not difficult to see how serious medico-legal problems may arise. It is believed in not a few instances ptomaines have been mistaken for the vegetable alkaloids in chemico-legal analyses.

For our knowledge concerning the ptomaines we are indebted very largely to the investigations of Selmi, Nencki, Gautier and Brieger. Selmi was the first (1874–77) to suggest the name—ptomaine—and in fact the first to announce their true nature and origin. Nencki was the first (1876) to isolate a ptomaine (collidine) in pure form and determine its chemical formula. Gautier has given the best classification of both the ptomaines and leucomaines. To Brieger, however, belongs the credit of isolating the largest number (nearly one half) of the known ptomaines and of giving us the best methods for their determination. Vaughan and Novy in this country have made some valuable researches along this line. As the result of an investigation of a number of cases of cheese poisoning they succeeded in isolating a substance which when administered to animals produced symptoms quite similar to those caused in the human subject by the poisonous cheese. To this they gave the name tyrotoxicon. This poison or one very similar has also been isolated from ice cream and milk. The chemical composition of tyrotoxicon has not as yet been definitely determined.

In foods like cheese and certain sausages which depend for their flavor on the action of certain microorganisms it is not strange that we should at times have the formation of poisonous compounds. The so-called process of "ripening" as applied to food products is in fact a partial putrefaction in which we have as the result of bacterial action the formation of ammonia compounds and amino acids which render the food more palatable. It is therefore not a matter of surprise that we should have at times a condition of "over-ripening" with the formation of chemical compounds of a poisonous character. It is to be borne in mind that ptomaines are not found only as the result of advanced putrefaction. Rather are they the products of the earlier stages of protein decomposition. In advanced putrefaction they may themselves be broken down into more simple compounds. Thus

Brieger isolated from a putrid mixture a ptomaine (peptotoxin) which he was unable to find when the putrefaction was more advanced.

The symptoms of ptomaine poisoning vary in kind and severity, depending on the nature and quantity of the poison consumed. These may be wholly or in part referable to the gastro-intestinal system. As a result we may have vomiting, abdominal pain, diarrhea or constipation, usually attended with great prostration. In a majority of the cases there is evidence of involvement of the central nervous system and in some cases the symptoms are wholly of a nervous character. Prominent among these are disturbances of vision and dryness of the mouth and throat. There may be fever or a subnormal temperature. Very often there is great weakness, rapid pulse and a tendency to collapse. Other symptoms which may or may not be present are vertigo, dyspnoea, convulsions, delirium and various skin eruptions. In some cases the symptoms simulate very closely poisoning by one of the vegetable alkaloids.

There is little room to doubt that many cases of acute illness are the direct result of some form of bacterial poison consumed with the food but which in isolated cases are not always recognized as such and often called by other names. It might be said that this factor in causing sickness finds but scant recognition save in those instances where a number of persons in a community are similarly stricken at the same time.

The prophylaxis of ptomaine poisoning resolves itself into the prevention as far as possible of the bacterial invasion and decomposition of our foods and food products. Certain foods like chopped meats, cooked potato and milk and the milk products lend themselves most readily to the growth of microorganisms and for this reason are to be the more carefully guarded.

Canned goods, especially the canned meats, are frequently the source of ptomaine poisoning. This results from the fact that they are not always perfectly sterilized before sealing, and, being often held in storage for a long time, an excellent opportunity is afforded for the formation of putrefactive poisons. Canned goods should in no case be consumed if there is any evidence of gas formation as shown by "blown" cans or the escape of gas on opening the can or, if there is any rancidity or putridity of the contents.

Fish, oysters and other sea foods undergo putrefactive changes very speedily and in so doing are very prone to form poisonous products. Several of the ptomaines were first isolated from the decomposed flesh of fish. Mitilotoxin (possibly a leucomaine), the most powerful of this class of poisons, was first obtained from mussels.

Great care should be taken to avoid eating fish or any of the sea foods which show the slightest evidences of putrefaction.

Heat of sufficiently high degree is destructive to all bacteria and is

largely depended upon to render harmless any disease-producing germs that may be contained in our food. While this is true of bacteria it is not true of all the products formed by them. Certain ptomaines and toxins may be destroyed by heat. Others are not susceptible to its influence. Therefore heat as employed in the process of cooking can not be regarded as a safeguard against ptomaine poisoning. Moreover it is often after cooking that these poisons are formed. Many of our cooked foods constitute the very best kind of culture media and as a result putrefactive changes may take place in them very rapidly. The safe plan is therefore to eat food soon after cooking or if it is reserved for any length of time it should be well protected from bacterial invasion and kept at a low temperature.

Cleanliness and low temperature afford the best means at our command for preserving foods from bacterial action—cleanliness to prevent the presence and contaminating influence of the millions of bacteria, often of the putrefactive type, which are always to be found where dirt and filth of any kind is allowed to accumulate and where flies and other insects are given free access, and low temperature to prevent the multiplication of those already in the food, no matter how careful we may have been to exclude them. Cold, even a freezing temperature, is not fatal to bacteria, but it does decidedly retard their growth. Even at the temperature of the ordinary refrigerator (about 10° C. or 40° F.) we find that most organisms multiply very slowly and as a result putrefactive changes are much retarded. Refrigeration is therefore a necessity for the proper keeping of foods, at least during the hot season. But to be efficient the refrigerator must be properly managed. Unless it be kept clean, properly ventilated and well supplied with ice it is practically useless, in fact absolutely dangerous.

Public sentiment is now demanding that those who produce and handle our foods should furnish them to us in a pure and wholesome condition and sanitary officials on every hand are endeavoring to enforce the proper regulation and protection of our food supply. This effort is most commendable. It is well to remember, however, that official regulation can extend only to our doors and to be fully effective it must be supplemented by proper management in our homes and in all places where food is consumed.

In conclusion, we must admit that well-defined cases of ptomaine poisoning are comparatively of rare occurrence when we consider the amount of food consumed and the number of consumers. They would indeed be exceedingly rare if those who are charged with the preparation and handling of our foods would always exercise the proper precautions along the lines we have indicated.

SCIENCE AND INTERNATIONAL GOOD WILL

By J. McKEEN CATTELL

SCIENCE with its applications has been one of the principal factors leading to peace and international good will. Science, democracy and the limitation of warfare are the great achievements of modern civilization. They have advanced together almost continuously from the beginnings of the universities of Bologna, Paris and Oxford in the twelfth century to their great triumphs in the nineteenth century and the present promise of their complete supremacy. It may be urged reasonably that science is the true cause of democracy and that science and democracy together are the influences most conducive to permanent and universal peace.

The applications of science in industry, agriculture and commerce, in the prevention of disease and of premature death, have abolished the need of excessive manual labor. It long ago became unnecessary for the great majority of the people to be held in bondage in order that a few free citizens might have education and opportunity, and slavery has been gradually driven from the world. The vast progress of scientific discovery and invention in the nineteenth century has reduced to a moderate amount the daily labor required from each in order that all may be adequately fed, clothed and housed. The death-rate has been decreased to one half; the ensuing lower birth-rate has freed nearly half the time of women and reduced proportionately the labor of men. The period of childhood and youth may be devoted to universal education, and equality of opportunity can be given to all. It is no longer needful to depend on a privileged class to conduct the affairs of government and to supply men of performance. Those selected from all the people as most fit can be given the preparation and opportunity needed to enable them to become leaders, and every one can take an intelligent share in political affairs and in appreciation of the higher things of life.

In giving us democracy science has made its greatest contribution to the limitation of warfare. It must be admitted that a democratic people may be inflamed into a mob mad for war; but this is not likely to happen in the case of a war of policy or of aggression. In the past wars have been more often due to the ambitions, difficulties and intrigues of kings and princes than to the passions of the people, and the decrease of wars has been largely a result of the establishment of constitutional governments and of the legalization of the methods of conscription and taxation. If a declaration of war or an ultimatum leading to war were subject to a referendum, the vote being taken not too

promptly, and if the estimated cost of the war were collected in taxes in advance, there would not be many wars.

We are still far from having a true political and social democracy. The production of wealth has increased rapidly; but we have not learned to distribute it justly or to use it wisely. The education supplied by our schools is inadequate and inept. We may be confident that a complete democracy will be the strongest force for peace that the world has seen. Even now the great mass of the people, most of them having some education and some property, are the true guarantees against wanton war. A king can no longer summon his nobles and the chiefs gather together their retainers to invade a foreign country. A war which, with its accompanying pestilence and famine, would reduce the population of a country to one half, as in the case of the thirty years' war, is now almost inconceivable. And this we owe to social and political democracy, which in turn we owe to science.

As a result of scientific progress and invention, the law of Malthus has been reversed. The means of subsistence increase more rapidly than the population. The sinister voluntary limitation of childbirth, which may give rise to racial deterioration and actual depopulation, is unnecessary. As population increases under a given condition of culture, the number of men of genius and talent competent to make the labor of each more efficient increases in proportion; as their inventions are of benefit to all, the means of subsistence tend to increase as the square of the population. As the level of education and culture is raised, and as democracy is perfected, so that each is given opportunity to do the work for which he is fit, the wealth and means of subsistence increase still more rapidly. The law of Malthus and the law of diminishing returns, like the law of the degradation of energy, may ultimately prevail, but not in any future with which we are concerned. The population of a civilized country, in which science is cultivated, need not be limited by famine, pestilence or war. Over-population and the need of expansion by conquest are obviated by democracy and science; the cause of war which may be regarded as inevitable and legitimate is thus abolished. In providing adequately for the subsistence of an increasing population, science has made a contribution to peace the magnitude of which can not be easily overstated.

Another great service for peace to be credited to science is the development of commerce, travel and intercommunication. Steam and electricity are handmaids of peace. Trade disputes and the misadventures of missionaries, travelers and immigrants may serve as causes or pretexts of wars, but the balance of commerce, travel and immigration is large on the side of peace. With the existing commerce among the nations, each dependent on every other, a war of any kind does injury to all. A nation at war destroys its own property throughout the world, and all the nations suffer. A neutral nation can no more afford

to countenance a needless war than mobs burning its own cities and killing its own citizens. In New York, London, Berlin and Paris are business houses and representatives of every country in the world. How could any nation wish to destroy or to permit the destruction of these cities?

Ease of travel and quickness of communication hold the large nations and empires together and tend to make the whole world one people. Racial prejudices are sometimes aggravated by close contact; but the acquaintance that comes with business and travel, with knowledge of politics and customs, with daily news cabled about the world, makes foreigners human like ourselves, and killing them becomes murder rather than war. The first cabin and the steerage of every transatlantic liner conduce to acquaintance and friendliness. Ease and cheapness of transportation have led to immigration on a vast scale. Many peoples must include New York when they enumerate their larger cities. Immigrants and their children in this country are numbered by the tens of millions. There are more people with Irish blood in the United States than in Ireland, and the same condition will in the end hold for other nationalities smaller than our own. Men war with their own kindred, but do not readily unite with aliens against them. The admixture of races, which the applications of science have so greatly promoted, surely makes for peace. This is especially the case when close communication is maintained with the mother country, such as is now supplied by the post-office, money order system, newspapers, ease of travel and other conditions of a civilization based on the applications of science.

Science has given us democracy, it has given us ample means of subsistence, it has given us commerce and intercommunication, and these three achievements are the principal factors which have lessened warfare and will eventually lead to its complete abolition. Other contributions of science, though less momentous, are by no means unimportant. Warfare is now in large measure applied science, and this tends towards its decrease. Wars between nations with scientific equipment and savage and barbarous peoples are no longer waged on equal terms and are of short duration. The extermination, despoliation and subjugation of the non-Caucasian races may be the world's great tragedy, and in so far as some of these peoples are able to adopt our science there will be a readjustment which may be written in blood or may be a triumph of common sense and justice. However this may be, the invincibility that science has conferred on the western nations has made them safe from attack and invasion, and while it may on occasion have led to wanton aggression, it has, on the whole, limited warfare. If we call to mind the centuries of invasion and threats of invasion by Northmen, Ottomans and Saracens, we can appreciate the value of the means of defense which science has given to the civilized nations.

The making of warfare an applied science by the western nations and by one eastern nation has tended also to prevent war between nations so equipped. When war is a game of skill rather than of chance, it is likely to be undertaken only after careful consideration of the conditions and consequences. The cost is enormous and must be carefully weighed. The interests of the money lenders are usually on the side of peace and become increasingly so as war continues. If war does occur between two great nations it is likely to be of short duration. It can not drag on through tens of years as formerly. Its horrors are also reduced; non-combatants are not so much concerned, and soldiers suffer less from disease—far more dreadful than violence—owing to the shorter duration of wars and to hygiene, medicine and surgery. It may be hoped that science has accomplished, on the whole, more for defense than for aggression; torpedoes, mines, submarines and aeroplanes are more effective for protection than for attack. The cost of modern armaments is so immense that this in itself will lead to their limitation and to the settlement of difficulties otherwise than by appeal to arms.

There is a psychological aspect of modern scientific warfare, which tends to discredit it. The heroism and the bravery, the excitement of personal contact and the exhibition of personal prowess, the romance and the occasional chivalry, are largely gone. Men cooped up in battleships or displayed like pawns on the field are not much greater heroes to themselves or to others than workers in a mine exposed to nearly equal danger. Officers under constant instructions from the seat of government and telegraphing their orders from a point of safety fall to the level of ordinary men of affairs. Tin soldiers will not forever stir the imagination of children in the nursery. Providence is on the side favored by the money lenders and having the best organized commissariat. War becomes brutal and disgusting; at its best like the business of the hangman, at its worst like infanticide.

War, wine and women as a toy have been so continuously exploited by poetry and art, that a philosopher might well propose to banish such incitements to misconduct from his republic. It is obvious that these things, bred into our blood through long ages when they were useful or at all events natural, stir the emotions and the passions in a way that can not be expected from considerations regarding peace, sobriety and the care of infants. Even religion is primarily racial in its expression. The churches of a nation may on the first day of every month repeat the prayer:

> Up Lord, and help me O my God; for thou smitest all mine enemies on the cheek-bone; thou hast broken the teeth of the ungodly.

Its people may unite in the anthem:

> O Lord our God arise,
> Scatter our enemies,
> And make them fall;

Confound their politics,
Frustrate their knavish tricks,
On thee our hopes we fix,
Oh save us all.

Religion, poetry and art have been of untold value to tribes and peoples; they will surely adjust themselves to the world as it now is and should become. Science needs no reconstruction; it is by its nature universal and gives a common interest and object to all nations. A scientific advance or discovery made in one place is equally true and equally important everywhere. When a state appropriates money for research or when a university or scientific foundation is endowed by private gift a contribution is made to the welfare and to the peace of the whole world. Smithson, an Englishman, might well establish the institution that bears his name in the United States: it is for the "increase and diffusion of knowledge among men."

The methods of science and the spirit of science are adverse to the jealousies, resentments and passions which lead to war. Dependence on hypotheses and induction tends to careful weighing of facts and delay before coming to conclusions. The quantitative method, the application of mathematics and probability, enables us to measure our knowledge and our ignorance. The genetic method discredits revolutions and catastrophes; it gives us faith in the slow processes of evolution. The writer, a psychologist by profession, knows very well that a scientific man may be correct and cautious in his researches, but unwise and rash in other relations of life. None the less it is true that the spread of scientific education and of scientific investigation is slowly leading to objective points of view and moral conduct in daily life. The scientific spirit is a pervasive and permanent force making for the world's peace.

Science not only gives us peace, but also the means to make worthy use of peace. An industrial civilization in which each has as many comforts and is spared as much misery as may be strikes our inherited instincts as a tame and tiresome Walhalla. But science gives us an object; it can even satisfy the inborn spirit for excitement and adventure. The frontiers in the wilderness disappear as civilization encircles the earth; but the frontiers of science will always become larger and more remote as they are further extended. War between nations may become inconceivable; but however numerous may be the battles waged and won by science, there will always be unconquered worlds beyond. The hundred thousand physicians of our country, its fifty thousand engineers, its ten thousand men of science engaged in research, form an army more inspiring to the imagination than soldiers idling in barracks or confined in the venereal wards of hospitals. The dealing with germs of disease, with poisons, explosives and radiations, is not less heroic than the risking of life on the battlefield.

A scientific man has relations with his fellow workers in the same field throughout the world. In some narrow specialties he may know that his paper will be read by not more than twenty people who may be citizens of ten different nations. He belongs to a social group or fraternity which is independent of language or nationality. A scientific subject, whether large or small, is built up by contributions accruing from many nations. The symbols of mathematics, physical constants, the names of species and genera, in large measure the terminology of all the sciences, form an international language. It is easy to read scientific literature in English, German and French; practically all those engaged in research work can do so. Communication by way of the mails and the printing press and interest in a common subject lead to personal contact and acquaintance, which have been especially forwarded by the university. When the present writer was assistant in the psychological laboratory of Professor Wundt at Leipzig twenty-five years ago, more than half the research students came from beyond the borders of Germany. They now hold professorships in universities in many different countries. In the classes of the writer at Columbia University last year, there were represented Great Britain, Germany, France, Italy, Russia, Denmark, Bulgaria, South America and Japan. Interchange of professors as well as of students has become a feature of academic life. Scientific men from foreign nations are continually visiting our institutions and lecturing at our universities. Each is an ambassador of peace and good will.

The common interests of scientific men have led to their organization in international conferences and congresses. These bodies are more numerous than is commonly known. The Central Office of International Institutions at Brussels, which aims to become a clearing-house in its field, enumerates as many as 280, most of which are concerned with science in its wider aspects. Dr. P. J. Eijkman, of the Hague, in his *L'Internationalisme scientifique* gives a list of 614 societies and organizations in the main scientific and international in character. International congresses devoted to each of the sciences and to the applications of science in the various branches of engineering and medicine meet periodically, each time in a different country. Experience shows that the organization of an international congress is not always conducive to domestic peace, but such difficulties perhaps dispose us to appreciate all the more the good qualities of foreigners. Certainly these congresses, bringing together men from different nations and giving them opportunity to cooperate for their common ends, have a real and increasing influence toward international good-will.

International congresses, conventions and conferences often lead to permanent plans and institutions for international cooperation. Some of these, such as the Hague conferences, are directly concerned with preventing wars or ameliorating their conduct. Others, such as the

postal and copyright conventions or the International Bureau of the American Republics, are semi-scientific in character. Still others are concerned with the applications of science or with scientific research. Examples of these are the International Bureau of Weights and Measures at Paris, the International Geodetic Bureau at Strasburg, the International Institute of Agriculture at Rome, the International Catalogue of Scientific Literature at London, the Nobel Institutes at Stockholm and the Naples Zoological Station. There are international committees on electrical units, on mapping the earth and the skies, on deep-sea exploration and the like. We have attained a common calendar and a meridian of Greenwich with standard time. The metric system is becoming universal, and there is no reason why the gram of pure gold should not be adopted as a monetary standard. The exact definition of boundaries and other applications of science to international questions do away with the misunderstandings that may lead to war.

International cooperation in science and scholarship and in their applications has reached such dimensions that it may be that the time has come when a truly international university might be established to advantage. If each nation would reduce its armaments to the extent of one per cent. and devote the money to the establishment and support of an international university, this step would in itself reduce the risks of war by more than one per cent. Such an institution could consequently be established without cost, and would be of vast intellectual, social and economic benefit to the world. It could be placed in Holland, Belgium or Switzerland, or perhaps still better in a territory made international for the purpose, such as one of the channel islands or Monte Carlo, wherever conditions of access, climate and environment would be most favorable. The conduct of such a territory and institution would give profitable practise in international cooperation. The high traditions of the university would be made tributary to international good-will and would themselves be further developed for the benefit of universities everywhere. Libraries and museums of international scope for the preservation of standards, type specimens, archives, etc., might to advantage be gathered together. Research institutions could be established by states or by private endowment: for the scientific work which is not primarily of benefit to a single individual or even to a single nation, can most properly be supported by all. By the establishment of an international university the nations would in part repay, or at least acknowledge, the debt which they owe to science for its services on behalf of the peace and welfare of the world.

The Rockefeller Institute for Medical Research.

THE PROGRESS OF SCIENCE

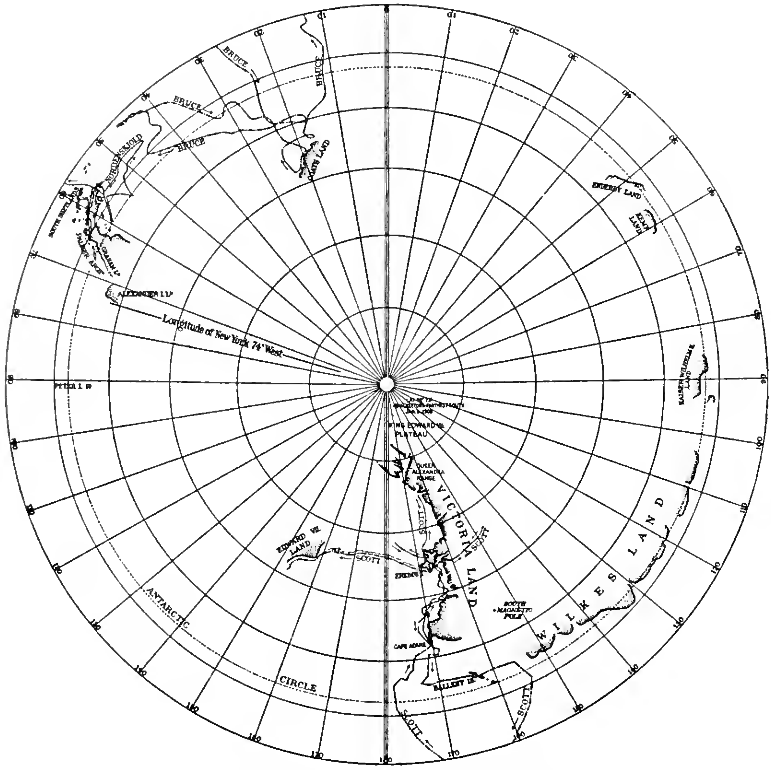
THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

The Rockefeller Institute for Medical Research has issued an interesting brochure giving an account of its history, organization and equipment. The institution was incorporated in 1901 with a board of directors consisting of seven distinguished pathologists, at which time Mr. John D. Rockefeller pledged a sum of $200,000 to be given in ten annual installments. At the end of the first year, he promised an additional sum of a million dollars for a building and support, and in that year the Schermerhorn estate on the East River, between 64th and 67th Streets, was purchased. Buildings were erected costing about $300,000, the formal opening taking place on May 11, 1906. In the following year Mr. Rockefeller gave an endowment of over two million, six hundred thousand dollars, and in 1908 arrangements were made for the construction of a hospital which cost $900,000. Other gifts followed from Mr. Rockefeller and the endowment fund now amounts to over $7,000,000.

At first the funds of the institute were used only for grants to investigators, but in 1902 Dr. Simon Flexner, then professor in the Johns Hopkins University, was elected director, and in 1904 research was begun by the institute. The original staff included, in addition to Dr. Flexner, Drs. S. J. Meltzer, E. L. Opie, H. Noguchi, P. A. Levene and J. Auer. Dr. Opie has since removed to St. Louis, and the scientific staff has been strengthened by the addition of Drs. Jacques Loeb, Alexis Carrel, Rufus Cole and other distinguished investigators. The original directors of the institute agreed in 1908 to become themselves a board of scientific directors, and to transfer to a board of trustees the management of the property. Both boards appear to form the corporation, their relations being somewhat unusual. The present board of trustees was appointed by the board of scientific directors, but they will in future be selected by the trustees. The arrangement, however, gives much more influence to scientific men than the organization of our universities, as the board of scientific directors retains control of the scientific work supported by the annual income, and one third of the trustees holding the property are men of science who are also members of the board of scientific directors.

The laboratory building is a fireproof structure of light gray brick and limestone, commanding a beautiful view of the East River and the country beyond. There are laboratories of pathology, bacteriology, chemistry, physiology, pharmacology, experimental medicine and experimental surgery, each of which is under the charge of a member or associate of the institute with a staff of assistants. The hospital includes a main building and an isolation pavilion for contagious diseases. Its capacity is about seventy beds and its work is confined to selected cases bearing on a limited number of diseases, those first selected having been acute lobar pneumonia, infantile paralysis, syphilis and certain types of cardiac disease. No charge is made for persons treated in the hospital, and all discoveries and inventions made by those working in the institution become its property to be placed freely at the service of the public.

The institution publishes *The Journal of Experimental Medicine*, a series of monographs and a series of studies. In its first ten years the institute has produced a large number of researches of great importance both for pure science and for applied medicine. Some of these have been described in this journal by the director, Dr. Flexner,



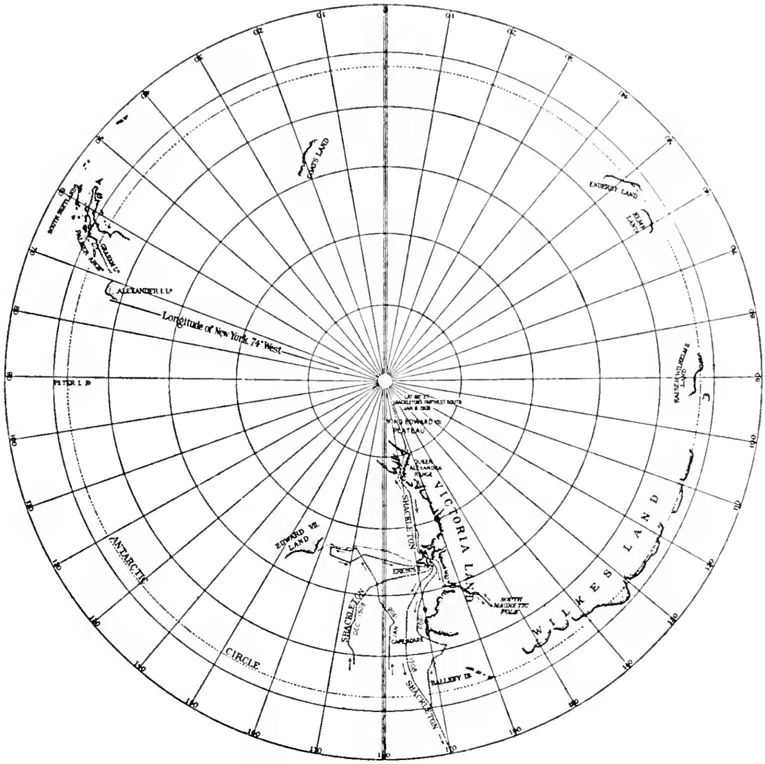
ROUTES FOLLOWED BY OTTO NORDENSKJÖLD, 1902–1903; R. F. SCOTT, 1902–1904; W. S. BRUCE, 1903–1904.

and we hope that it may be possible to publish here other articles containing accounts of work that in importance is not exceeded by that being accomplished in any science in any part of the world.

EXPLORATION AND ADVENTURE IN THE ANTARCTIC

THE attainment of the South Pole is of dramatic and sporting interest to every one, and such expeditions are likely to yield scientific results of value. There is a dramatic appeal in the fact that the most remote and inaccessible ends of the earth have at least been brought within reach, in the north by Commander Peary and now in the south by Captain Amundsen. These quests have to a certain extent been international games of skill and endurance. In the present instance this aspect has been emphasized by the fact that Captain Amundsen secretly departed from his planned expedition to the Arctic to engage in the race with Captain Scott. We may hope that both reached the goal. It is not a matter of consequence whether it was first attained by a descendant of the vikings or by the people that sent Cook, Weddell, Ross, Scott and Shackleton to press each further than his predecessor to the south. The Monroe doctrine presumably does not include in its scope the Antarctic continent; but it seems unfortunate that we have done less than our share to explore the land immediately south of us.

It probably does not violate the copyright so carefully guarded by the New York *Times* on behalf of Captain



ROUTE FOLLOWED BY E. H. SHACKLETON, 1908–1909.

Amundsen to state that the explorer reached the pole on December 14, and remained there for three days. The sun was bright, and observations were carefully made with the sextant and artificial horizon. The great snow plane elevated more than 10,000 feet above the sea was named King Haakon Plateau, though it may be that priority should be given to the name of King Edward VII. Land, as the plateau extends to the point within ninety-seven miles of the pole reached by Lieutenant Shackleton on January 9, 1909. The *Fram,* made famous by Dr. Nansen's expeditions, reached the Bay of Wales, south of New Zealand at a latitude of 78 degrees and 40 minutes on January 14 of last year. There it was seen by the *Terra Nova* of Captain Scott's expedition, and news was thus first given to the world of Captain Amundsen's plans.

The trip to the pole was begun on October 20 and proceeded without noticeable event at the rate of twenty miles a day. The general course can be traced on the maps, showing the course of previous expeditions, reproduced here by courtesy of the American Museum of Natural History. The cold and blizzards were a serious hindrance, but not so bad as traveling over the floating ice floes in the north without the possibility of establishing depots for food and being assured of a return by the same route. The great ice plane without a trace of life appeals to the imagination, but traversing it has probably not added considerably to our scientific knowledge, and there does not seem to be much likelihood of economic

gains. The coal discovered by Lieutenant Shackleton is only of scientific interest in showing the changes that have taken place in the climate.

Captain Amundsen, who had already won fame by traversing the Northwest Passage, probably regards his expedition to the pole as only an episode, and will proceed with his plan to drift with the ice across the north polar regions.

SCIENTIFIC ITEMS

We regret to record the death of Dr. John Bernhardt Smith, state entomologist of New Jersey and professor of entomology at Rutgers College; of Professor Mason Blanchard Thomas, professor of botany at Wabash College; of Dr. Charles Robert Sanger, professor of chemistry and director of the chemical laboratory at Harvard University; of Dr. Henry Taylor Bovey, F.R.S., formerly professor of civil engineering in McGill University, and of Professor Osborne Reynolds, F.R.S., the distinguished engineer and physicist.

Mr. Samuel Henshaw has been appointed director of the Museum of Comparative Zoology of Harvard University.—Professor Charles Sedgwick Minot has been selected by the German government as Harvard exchange professor at the University of Berlin for 1912–13. Dr. Rudolf Eucken, professor of philosophy at Jena, has been appointed exchange professor at Harvard University.—Dr. Talcott Williams, associate editor of the Philadelphia *Press*, has been appointed director of the School of Journalism of Columbia University, founded by Mr. Pullitzer. Professor John W. Cunliffe, now head of the department of English of the University of Wisconsin, is the associate director of the school.

For the meeting of the British Association for the Advancement of Science, which is to be held this year at Dundee, beginning on September 4, under the presidency of Professor E. A. Schäfer, F.R.S., the following presidents have been appointed to the various sections: Mathematical and Physical Science, Professor H. L. Callendar, F.R.S.; Chemistry, Professor A. Senier; Geology, Dr. B. N. Peach, F.R.S.; Zoology, Dr. P. Chalmers Mitchell, F.R.S.; Geography, Sir Charles M. Watson, K.C.M.G., C.B., R.E.; Economic Science and Statistics, Sir Henry H. Cunnyghame, K.C.B.; Engineering, Professor A. Barr; Anthropology, Professor G. Elliot Smith, F.R.S.; Physiology, Mr. Leonard Hill, F.R.S.; Botany, Professor F. Keeble; Educational Science, Professor J. Adams; Agriculture, Mr. T. H. Middleton.

The treasurer of Columbia University has reported to the trustees that he had received about $1,550,000 from the executors of the estate of the late George Crocker. Accordingly, the work of cancer research, for which Mr. Crocker gave this sum as an endowment, will begin at once.

THE POPULAR SCIENCE MONTHLY.

MAY, 1912

NEW PROOFS OF THE KINETIC THEORY OF MATTER AND THE ATOMIC THEORY OF ELECTRICITY

By Professor ROBERT ANDREWS MILLIKAN, Ph.D., Sc.D.

UNIVERSITY OF CHICAGO

IT is my purpose herein to review the history of two of our most fundamental physical theories and to present some very simple and easily intelligible experiments which demonstrate the correctness of these theories, though they are by no means the only experiments which lead to the same goal.

If this statement seems too dogmatic and positive to be scientific let me say that I make it advisedly, for I wish vigorously to combat the point of view which I fear too many of those who are not engaged at first hand in scientific inquiry gain, both from the "revolutionary discoveries" which are continually being announced by the daily press, and also from the prominence which scientists themselves naturally give to the demolition of time-honored hypotheses in which they do not believe—the point of view that none of the theories of the scientists are after all any more than transient phenomena, that they are all just a part of the continual change and flux of things, that this generation discards wholesale all the hypotheses which were held adequate in the last and that the next generation will make equally short work of all the theories which hold sway to-day. In opposition to that point of view I wish to assert that there are some things, even in science, which we may safely say that we know, that there are some theories which we may be reasonably certain are going to endure—that in fact we may divide the theories of science into three categories, with broad and indefinite lines of division between them, it is true, but yet with real dividing areas, if not dividing lines.

In the first category may be placed the theories which we may say that we *know* are correct, using the word "know" not in the abstract

philosophical sense, but in the common every-day intelligible sense. As an illustration of theories which are in this category we may take the germ theory of disease, meaning by that the theory that some diseases at least are due to definite micro-organisms which invade the system. In 1850, before Lister's and Pasteur's discoveries this was a pure hypothesis. To-day it is an hypothesis which has been definitely proved to be correct, and which henceforth we may indeed extend and modify but which we need never expect to see abandoned.

Again, the hypothesis that the earth is a round ball, rotating daily on its axis, and swinging annually around the sun was a few hundred years ago a mere assertion which almost nobody believed; to-day it is an established doctrine which we may count upon to endure, though of course the earth may not always keep on doing what it is doing to-day.

In the second category are a large group of theories which are probably correct, but which may at any time be proved to be false; while in the third category are theories which are very uncertain, some of them being little more than "pipe dreams," the best perhaps which we can do in the present state of our ignorance, but the ignorance upon which they are based is after all abysmal. The nebular hypothesis was a fine illustration of one of these dreams. It was not a part of our knowledge, because, as Kelvin so well says, there is no knowledge until we have been able to apply exact quantitative tests to our hypotheses. In other words, there is no science without exact measurement. There may be many good guesses without it, many plausible explanations, but no real knowledge. Such exact quantitative tests the nebular hypothesis has never been able to call to its support.

Now the progress of science consists simply in the slow but continuous sweep of these two broad lines of division in the direction of the last category, that is, it consists in nothing else save the continual transfer of theories from category 3 over to 2 and from 2 over into 1, and it is my purpose herein to trace the most fascinating history of the gradual transfer of two of these theories, from the outermost edge of 3 across the two boundaries over into 1, where they now rest so securely established that it is not too much to say that there is as much likelihood that man will some day cease to believe in the rotation of the earth as that the kinetic theory of matter and the atomic theory of electricity will ever cease to be the corner stones of all physical science.

But first, just a word about these revolutionary discoveries which are continually being announced. Nine tenths of them are just as revolutionary as was the discovery of the seven-year-old boy who came home from school one day altogether disgusted, saying that for a week his teacher had been telling him that 3 and 4 made seven, and he had just got it well learned when she told him that 5 and 2 make seven. So it is with our discoveries in science. We do indeed discover new relations,

but for the most part the old ones remain. The atomic theory of matter, for example, was not even touched when radio-activity and the divisibility of the atom were brought to light, for nobody who had gone beyond the high school stage in science ever thought of asserting an indivisible atom, and that simply because we had no basis for asserting anything about the insides of the atom. We knew that there was a smallest thing which took part in chemical reactions, and we named that thing the atom, leaving its insides to the future, and the future proved itself abundantly able to take care of the trust.

Coming now to the first of our two theories, it is probably carrying coals to Newcastle to explain to an intelligent audience to-day what are the essential elements of the kinetic theory of matter, but I will at least carry enough of these coals to make a logical stepping-stone from the familiar to the unfamiliar.

The kinetic theory, then, when divorced from all non-essentials, is merely the assertion that everything in this world of ours is in a state of restless, ceaseless, seething motion, that all matter is composed of minute parts called molecules which are eternally pounding and jostling against one another. In gases these molecules are so far apart that the forces of attraction which exist between them are quite negligible and they dart hither and thither like gnats in a swarm, only with the stupendous speed of a mile a second (in the case of hydrogen) and richochette unceasingly against one another and the walls of the containing vessel, producing by this bombardment all the familiar phenomena of pneumatic tires and gaseous bodies generally. If you could magnify the air in an ordinary room just a thousand million times, that is, enough to make a good-sized marrowfat pea swell to the size of the earth, you would see objects about as big as a football—we will not say of what shape, because we do not know anything about it, but they would probably be of the same shape in a given gas—and if the motions would stop long enough to enable us to get a snap shot of the whole situation, you would see on the average one of these objects in a cubical space ten feet on a side. Then if you let them go again you would see each of these footballs shoot on the average through thirty such imaginary cubical rooms before it hit another. This distance we call the mean free path of a gas molecule.

In the liquid state the molecules are packed closely together by cohesive forces, yet they continually wriggle and squirm over and around one another, so that if you will be content this time with a 10 million-fold magnification, the liquid would look very much like a mass of wriggling squirming maggots—not a pretty picture perhaps, but a fairly accurate one I think.

In solids the molecules are for the most part locked up tightly in crystalline forms so that their motions are reduced to mere trembling,

unavailing protests against their hard imprisonment. If a biological analogy would make the picture more vivid you can imagine the cages of a menagerie arranged in squares or other regular figures, while the caged animals pace restlessly to and fro between their bars.

Increase in temperature means in all cases increase in the kinetic energy of agitation of the molecules, whatever state they may be in, and one of the fundamental assumptions of the kinetic theory, and one which we can now definitely prove, at least for gases, is that at a given temperature the average kinetic energy of agitation of a molecule is a universal constant, independent of whether the molecule is little or big. If the exact meaning of this statement is not clear, then imagine a lot of molecules of different weights from the big mercury unit down to the little hydrogen unit, one two-hundredth as heavy, led out in succession to a punching bag or to the striking machine at a county fair, and asked to register their strengths. They would, by virtue of a single impact, drive the index to just the same height, the lubberly mercury molecule being able to hit no harder, despite his size, than the tiny hydrogen molecule. This means of course that the hydrogen molecule must have a much larger speed, in fact a speed fourteen times as great in order to make up for his small avoirdupois. Such in brief is the kinetic hypothesis.

This hypothesis has had a long and checkered career in the course of which it has met with nearly all the vicissitudes which can befall a physical theory. Put forth in its most fundamental aspects by Leucippus and Democritus in the early dawn of Greek thought (about 440 B.C.) it was violently combated by the idealistic philosophers of the ancient world, especially by Plato and Aristotle, and remained altogether fruitless for two thousand years and more, in part, no doubt, because of the adverse influence of these great names. At the beginning of the modern awakening of the intellectual life it was resurrected by Descartes about 1630, and elaborated in considerable detail by Daniel Bernouilli in 1738. Nevertheless, up to the middle of the nineteenth century it remained to the world at large the rather fanciful and naïve speculation of a mere handful of philosophers. And although it is significant that this handful contains the names of the most prominent and productive of the makers of modern physics—Newton, Boyle, Rumford, Joule, Clausius, Maxwell, Kelvin, Boltzmann—nothing is more surprising to the student brought up in the atmosphere of the scientific thought of the present than the fact that the relatively complex and intricate phenomena of light and electricity had been built together into fairly consistent and satisfactory theories long before the much simpler phenomena of heat and molecular physics had begun to be correctly understood.

The first tremendous success of the kinetic hypothesis came about

the middle of the nineteenth century, when it gave birth to the principle of conservation of energy, a generalization which grew immediately and inevitably out of the mechanical theory of heat as it lay in the minds of Rumford, Joule and their co-workers. Between 1860 and 1890 the proofs of the kinetic hypothesis came in so rapidly through the brilliant work of such masters as Joule, Clausius, Maxwell, Kelvin and Boltzmann that the scientific world began to be convinced, and only here and there was found a man of standing among the scoffers. Then, about 1887, a reaction set in, and the school of energetics arose in Germany, which attempted to force the principle of conservation of energy to devour its own mother. The most spectacular of the onslaughts was made by Ostwald, who in 1895 wrote a widely circulated essay, entitled "The Demolition of Scientific Materialism," elsewhere printed under the title, "The Route of Modern Atomism." Led by such a bell-wether, the sheep began to jump back over the wall, and the results of that backward movement are still felt in the United States, particularly in high-school texts, despite the fact that to-day the opposition among scientific men to the kinetic hypothesis is absolutely gone, and even Ostwald has admitted his error. Indeed, so direct and so convincing is now the evidence that it is not too much to say that any one who wishes can now have immediate ocular demonstration of the perpetual dance of the molecules of matter.

But since we are here as much concerned with the atomic or granular theory of electricity as with the kinetic theory of matter, let us turn for a moment to consider the present status of our knowledge as to the nature of electricity. Unlike the kinetic theory of matter, the granular theory of electricity can boast of no great antiquity. Indeed, in its present form it is but ten or fifteen years old, and in no form is it more than one or two hundred years old. For there are no electrical theories of any kind which go back of our own Benjamin Franklin. It is true that the Greeks discovered that rubbed amber had the power of attracting to itself light objects placed in its neighborhood, but this is all until A.D. 1600, when Queen Elizabeth's surgeon, Gilbert, found that a glass rod and some twenty other bodies, when rubbed with silk, acted like the rubbed amber of the Greeks, and he consequently decided to describe the phenomenon by saying that the glass rod had become *electrified* (amberized, electron being the Greek word for amber) or had acquired a charge of *electricity*. In 1733, Dufay, a French physicist, further found that sealing wax, when rubbed with cat's fur, was also electrified, but that it differed from the electrified glass rod, in that it strongly attracted any electrified body which was repelled by the glass, while it repelled any electrified body which was attracted by the glass. About 1847, Benjamin Franklin adopted the following purely arbitrary convention, and said, We will consider that there are

two kinds of electrification, which we will distinguish by the terms positive and negative, and we will call any body positively electrified if it is repelled by a glass rod which has been rubbed with silk, and we will call any body negatively electrified if it is repelled by sealing wax which has been rubbed with cat's fur. These are to-day our definitions of positive and negative electrical charges. Notice that in setting them up we propose no theory whatever of electrification, but content ourselves simply with describing the phenomena. In the next place it was surmised by Franklin in 1750, and proved very accurately by Faraday in 1837, that when glass is positively electrified by rubbing it with silk, the silk itself takes up a negative charge of exactly the same amount as the positive charge received by the glass, and, in general, that positive and negative electrical charges always appear simultaneously and in exactly equal amounts. So far, still no theory! But in order to have a rational explanation of the phenomena so far considered, particularly this last one, Franklin now made the assumption that something which he chose to call the electrical fluid or "electrical fire" exists *in normal amount* as a constituent of all matter in the neutral, or unelectrified state, but that more than the normal amount in any body is manifested as a positive electrical charge, and less than the normal amount as a negative charge. Æpinus, an English admirer of Franklin's theory, pointed out that, in order to account for the repulsion of two negatively electrified bodies, it was necessary to assume that matter, when divorced from Franklin's electrical fluid, was self-repellent, *i. e.*, that it possessed properties quite different from those which are found in ordinary unelectrified matter. In order to leave poor old matter, whose independent existence was thus threatened, endowed with its familiar old properties, other physicists of the day preferred to assume that matter in a neutral state shows no electrical properties because it contains as constituents equal amounts of *two* fluids which they called positive and negative electricity, respectively, and that a positively charged body is one in which there is more positive than negative, and *vice versa*. The two theories are not, at bottom, very different, since Franklin's modified one-fluid theory required that matter, when divorced entirely from the electrical fluid, have exactly the same properties which the two-fluid theory ascribed to negative electricity, barring only the property of fluidity; so that the most important distinction between the theories was that the two-fluid theory assumed the existence of three distinct entities, named positive electricity, negative electricity and matter, while the one-fluid theory reduced these three entities to two which Franklin called matter and electricity, but which might perhaps as well have been called positive electricity and negative electricity, unelectrified matter being reduced to a mere combination of these two. Whether the electrical fluid (or fluids) was supposed to

be made up of particles, or to be indefinitely divisible, is not usually stated, though Franklin himself certainly believed in the existence of an electrical particle or atom, for he says: "The electrical matter consists of particles extremely subtle, since it can permeate common matter, even the densest, with such freedom and ease as not to receive any appreciable resistance." When Franklin wrote that, however, he could scarcely have dreamed that it would ever be possible to isolate and study by itself one of the ultimate particles of the electrical fluid. The atomic theory of electricity was to him a pure speculation.

The first bit of experimental evidence which appeared in its favor came in 1833, when Faraday found that the passage of a given quantity of electricity through a solution containing a compound of hydrogen, for example, would always cause the appearance at the negative terminal of the same amount of hydrogen gas, irrespective of the kind of hydrogen compound which had been dissolved, and irrespective also of the strength of the solution; that, further the quantity of electricity required to cause the appearance of one gram of hydrogen, would always deposit from a solution containing silver exactly 107.1 grams of silver. This meant, since the weight of the silver atom is exactly 107.1 times the weight of the hydrogen atom, that *the hydrogen atom and the silver atom are associated in the solution with exactly the same quantity of electricity.* When it was further found in this way that all atoms which are univalent in chemistry, that is, which combine with one atom of hydrogen, carry precisely the same quantity of electricity, and all atoms which are bi-valent carry twice this amount, and, in general, that valency, in chemistry, is always exactly proportional to the quantity of electricity carried by the atom in question, it was obvious that the atomic theory of electricity had been given very strong support.

But striking and significant as were these discoveries, they did not serve to establish the atomic hypothesis. Indeed, the attention which Faraday himself directed to the rôle played by the medium which surrounded a body carrying a charge, or the wire through which a charge was passing (an electric current) led to a point of view which was distinctly antagonistic to the atomic concept of electricity. This point of view was emphasized very strongly by the followers of Maxwell, notably by Oliver Lodge, who through his book on "Modern Views of Electricity" influenced very largely the points of view adopted by the text-books of the last two decades of the nineteenth century. This view was that an electric charge is nothing more than a "state of strain in the ether," and an electric current, instead of representing the passage of anything definite along the wire, corresponded merely to a continuous "slip" or "breakdown of a strain" in the medium within the wire, whatever these terms may mean. Now there can be no doubt that

when an electrical charge is placed upon a body, the medium about the body becomes the seat of new forces, and this may be described by saying that the medium about the body has been thrown into a state of strain. But it is one thing to say that the electrical charge on the body *produces* a state of strain in the surrounding medium, and quite another thing to say that the electrical charge *is nothing but* a state of strain in the surrounding medium, just as it is one thing to say that when a man stands on a bridge he produces a mechanical strain in the timbers of the bridge, and another thing to say that the man is nothing more than a mechanical strain in the bridge. The practical difference between the two points of view is that in the one case you look for other attributes of the man besides the ability to produce a strain in the bridge, and in the other case you do not look for other attributes. So the strain theory, although not irreconcilable with the atomic hypothesis, was actually antagonistic to it, because it led men to think of the strain as distributed continuously about the surface of the charged body, rather than as radiating from definite spots or centers peppered over the surface of the body. Between 1850 and 1900, then, the physicist was in the following anomalous and inconsistent position: When he was thinking of the passage of electricity through a solution, he pictured to himself definite specks or atoms of electricity as traveling through the solution, each atom of matter carrying an exact multiple of a definite elementary electrical atom; while, when he was thinking of the passage of a current through a metallic conductor, he gave up altogether the atomic hypothesis, and attempted to picture the phenomenon to himself as a continuous "slip" or "breakdown of a strain" in the material of the wire.

About 1900, however, a great stride forward was taken when the atomic hypothesis began to be applied to metallic conductors as well as to solutions, and electrical currents, even in wires, began to be looked upon as due to the transport through the wire of discrete units of electricity, now beginning to be called *electrons,* these units being either handed on from atom to atom or else being pushed along through the interstices between the atoms. This point of view, which was a return to Franklin's way of thinking, found its new justification in the fact that it was found possible in vacuum tubes of the X-ray type to obtain from all kinds of matter very minute electrically charged bodies of negative sign, which under all circumstances showed exactly the same behavior in electrical and magnetic fields and which had a mass which was computed to be but 1/1,760 the mass of the atom of hydrogen, the smallest known atom of matter. There was indeed no direct proof that the charges of these bodies were all the same, since no method had been found of examining them individually, nevertheless, it was pretty conclusively shown, as early as 1899, by Townsend of Ox-

ford, that the mean value of the charge carried by these electrons was the same as the charge carried by the hydrogen atom in electrolysis; and about the same time Sir J. J. Thomson found a way of making a rough determination of the absolute value of this mean charge. This method was improved in 1902 by H. A. Wilson, now of McGill University, and actually formed the starting point some five years later of the work out of which grew, by a series of natural steps, the experiments which are herewith presented and which have made it possible to capture and make accurate measurements upon one single isolated

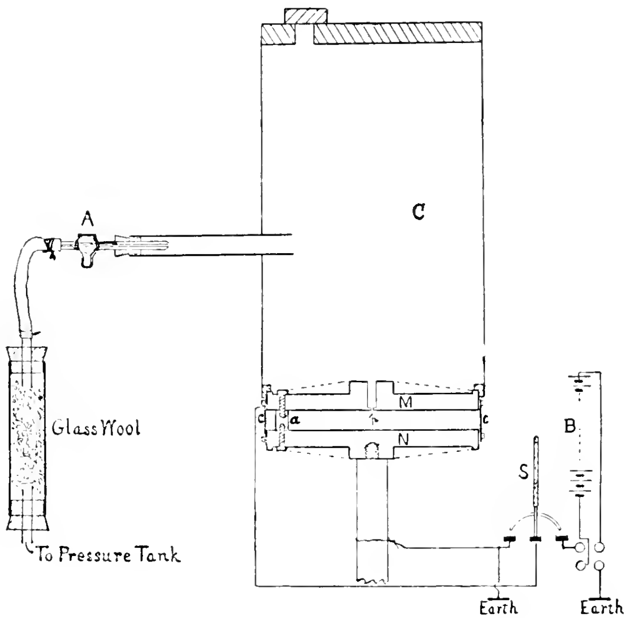


FIG. 1.

electron or any desired number of such electrons up to one hundred and fifty.

Imagine two circular plates *M* and *N* (Fig. 1) 22 centimeters (about 10 inches) in diameter and 16 millimeters ($\frac{3}{4}$ inch) apart which can be electrically charged, one positively and the other negatively, by making them the terminals of a ten-thousand-volt storage battery *B*. Suppose also that with the aid of a switch *S* the plates can be instantly discharged when desired so as to possess no electrical properties at all. Now when the plates are suddenly charged the air between them is found to remain perfectly quiet and free from convection currents of any kind—a result which shows that practically all of the air molecules between the plates are electrically neutral. But if now a beam of X-

rays is allowed to play upon the air between these two plates, it is found that some of these neutral air molecules are split up by the X-rays into electrically charged parts, which fly instantly, one part to plate M and the other part to plate N. This shows conclusively that the ordinary neutral molecules of the air possess electrical constituents, that is, that they contain equal quantities of positive and negative elec-

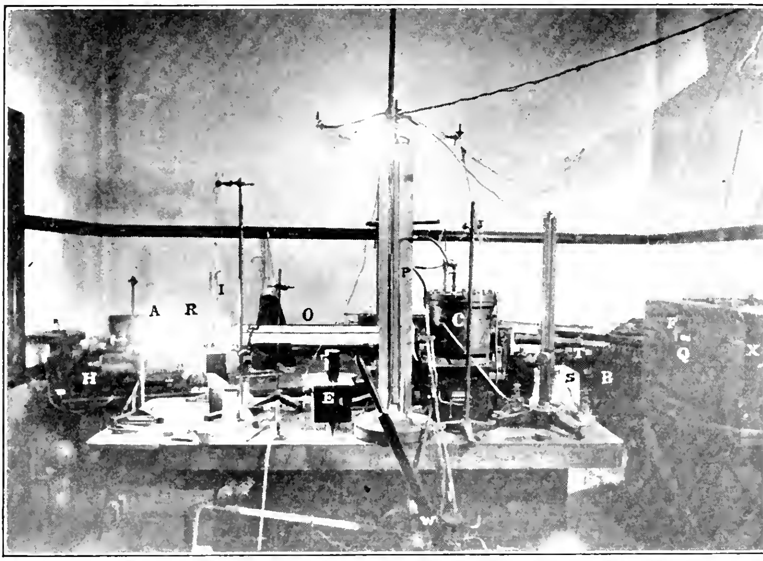


FIG. 2. *A*, arc light for illuminating droplet. *H*, chronograph for measuring speeds of droplet. *R*, lens for making the beam from the arc parallel or slightly convergent. *I*, shutter for intercepting altogether the light from the arc save when a reading of a transit of an "oil star" over a cross-hair was to be taken. This was used to insure entire stagnancy of the air between the plates *M* and *N* (Fig. 1). *E*, high potential static voltmeter from measuring *PD* produced by *B*. *P*, mercury pressure gauge or manometer for measuring the pressure of the air within *C*. *C*, air-tight brass chamber containing the plates *M* and *N* of Fig. 1. *W*, pressure pump for forcing a puff of air through the atomizer inside of *C* and above the plates *M* and *N*. The same pump is also used for exhausting the cylinder *C*. *T*, telescope for observing illuminated droplet. *S*, switch for throwing on or off the electric field between the plates. *B*, ten-thousand-volt storage battery. *T*, spot of light produced by the beam after passing through the two windows of the chamber *C*. *Q*, opening in lead box through which X-ray beam emerges on its way to chamber *C*, where it ionizes the gas between plates *M* and *N* of Fig. 1. *X*, X-ray bulb. *O*, cylindrical glass trough 80 cm. long filled with water for absorbing the heat rays from the arc.

tricity. Both ultra-violet light and the rays from radium possess, like the X-rays, the power of thus *ionizing* a gas, and even when no external ionizing agent whatever is at hand, it is found that out of the 27 billion billion molecules which are present in each cubic centimeter of ordinary air, from two to twenty split up per second into ions. As will presently be shown, this process of ionization consists in the detaching from a neutral molecule of an exceedingly minute fraction of its con-

stituent negative electricity—an electron—so that the residue of the molecule is probably just like the neutral molecules of the surrounding gas, save that it now carries a free or unbalanced positive charge corresponding to the negative charge of the electron which it has lost. The escaped electron probably soon attaches itself to a neutral molecule, so that shortly after the decomposition of a molecule, the gas is in the same condition as it was before the decomposition, save that two of its previously neutral molecules are now electrically charged, one positively and the other negatively. Whether this molecular decomposition which goes on continually in ordinary air is due to rays from traces of radio-active substances, which are present at all times in the air, or whether it is due to an occasional spontaneous explosion of a molecule, we can not as yet be absolutely certain, though the evidence is at present strongly in favor of the former hypothesis. But, however they may be formed, there can be no doubt of the presence of these ions in the atmosphere at all times, to the extent of from 1 to 15 per cubic millimeter, nor can there be any doubt that it is these atmospheric ions which are responsible for all the manifestations of atmospheric electricity which have been the object of man's awe and worship throughout all ages.

Now the problem which was set for this investigation was to catch individual ones of these atmospheric ions and to find what sort of charges they possess. A detective which could be set on the trail of a thing so small had evidently to be a distinctly undersized member of the force. It was in fact an oil-drop so minute as to be little more than visible through the most powerful microscope. In these experiments, however, no such high-power microscope was needed, for in a sufficiently powerful beam of light the oil droplet could be made to appear as a bright dot even to the naked eye in spite of its minuteness. The method of setting it at work was this. A spray of oil was blown from an ordinary commercial atomizer *A* into a dust-free chamber *C*, and one or more of the oil droplets was allowed to fall through a pin hole at *p* into the space between *M* and *N*. As it floated there, slowly falling under gravity, it was illuminated by a powerful beam from an arc light, which passed through diametrically opposite windows in the encircling ebonite strip *c*. It was viewed through a third window placed on the emergent side of the beam about fifteen degrees from its direction. A glance at the accompanying photograph, which shows a modification of the device, used for work at low pressures (see below), will make clear the arrangement of the different parts of the apparatus in the experiment now under consideration. The appearance of this drop of oil in the observer's short focus telescope through which it was viewed was that of a brilliant star on a black background. Be-

fore this star reached the lower plate the electrical field was thrown on and it straightway began to rise again toward the plate M. This was because in the atomizing process the droplet in general received a frictional charge; for, as is well known, strong frictional processes always produce electrification. If this charge was of the wrong sign to cause the drop to rise, rather than descend, when the 10,000-volt battery was thrown on, the signs of the charges on M and N were reversed. When the drop had been pulled up close to M the plates were discharged and the drop allowed to fall under gravity again until it was close to N. In this way, by alternately throwing on and off the electrical field, the oil drop detective was kept pacing its beat up and down between the plates in the hope that it would catch and hold some unwary ion which came within its reach. The first time the experiment was tried an ion was caught within a few minutes and the fact of the capture had been signalled to the observer by the change in the speed with which the drop moved up when the electrical field was on; for since the ion carried an electrical charge, its advent upon the drop changed the charge on the latter and therefore changed the speed with which it was pulled up toward M. If the sign of M was positive, then the drop itself, in order to be pulled up by the field, must have had a negative charge and in that case the capture of a positive ion reduced this negative charge and therefore reduced the speed in the field, while the capture of a negative ion increased the negative charge and hence increased the speed in the field. From the sign, then, and the magnitude of this change in speed, taken in connection with the constant speed under gravity, the sign and the exact value of the charge carried by the captured ion could be easily determined.

A drop would often be kept traveling back and forth in the manner described for four or five hours at a time, in the course of which it would change its charge twenty or thirty times because of the capture of ions and the value of each of these different charges would be computed. The beauty and precision of the measurements and the certainty with which the atomic theory of electricity follows from the results obtained can best be appreciated by inserting in full the record of an experiment made upon a particular drop. The column headed G gives the successive times which the droplet required to fall between two fixed cross-hairs in the observing telescope whose distance apart corresponded in this case to an actual distance of fall of .5222 centimeter. It will be seen that these numbers are all the same within the limits of error of a stop watch measurement. The column marked F gives the successive times which the droplet required to rise under the influence of the electrical field produced by applying in this case 5,051 volts of potential difference to the plates M and N. It will be seen that after the second trip up, the time changed from 12.4 to 21.8, indicating, since in

this case the drop was positive, that a negative ion had been caught from the air. The next time recorded under *F*, namely, 34.8, indicates that another negative ion has been caught. The next time, 84.5, indicates the capture of still another negative ion. This charge was held for two trips, when the speed changed back again to 34.6, showing that a positive ion had now been caught which carried precisely the same charge as the negative ion which before caused the inverse change in time, *i. e.*, that from 34.8 to 84.5.

	G	*F*
	13.6	12.5
	13.8	12.4
	13.4	21.8
	13.4	34.8
	13.6	84.5
	13.6	85.5
	13.7	34.6
	13.5	34.8
	13.5	16.0
	13.8	34.8
	13.7	34.6
	13.8	21.9
	13.6	
	13.5	
	13.4	
	13.8	
	13.4	
Mean	13.595	

Now all of the successive values of the charge carried by the drop throughout the experiment can be easily computed from the constant speed under gravity and the successive values of the speed in the electric field. To find the *absolute* values of these charges it is indeed necessary to know the weight of the drop, and the determination of this weight may involve an error of a fraction of a per cent. at most, but since this weight remains constant throughout the experiment the *relative* values of the successive charges can be found with absolute certainty and with great precision without any knowledge of this weight. They are in fact simply proportional to the successive values assumed by the sum of the two speeds, viz., that under gravity and that in the field.[1]

[1] For in the case of bodies moving slowly and uniformly through a resisting medium any two forces produce velocities which are proportional to the forces. The downward force due to gravity is here mg and the upward force due to the field is Fe, in which F denotes the strength of the field and e the charge on the drop. Hence, if v_1 is the downward velocity due to gravity and v_2 the upward velocity due to the excess of the upward pull of the field over the downward pull of gravity, we have

$$\frac{v_1}{v_2} = \frac{mg}{Fe - mg} \quad \text{or} \quad e = \frac{mg}{Fv_1}(v_1 + v_2).$$

Similarly the charge carried by any captured ion is proportional to the change produced in this sum by the capture. Now the change in this sum produced by the capture of the ion which caused the time in column F to change from 34.8 to 84.5 was, as any one who wishes can verify, .00891 cm. per sec. and the successive values of this sum arranged in order of magnitude were .04456, .05347, .06232, .07106, .08038. If now electricity is atomic in structure all the different charges appearing in this experiment, those on the ions and those on the drop, should be exact multiples of the elementary unit of charge, which means that all of the numbers above given should be exact multiples of something. Dividing the above five numbers by 5, 6, 7, 8 and 9, respectively, gives .008912, .008911, .008903, .008883 and 008931, which are all seen to be within one fifth of one per cent. of the value of the *change* in the sum of speeds produced by the capture of the ion which caused the numbers in the column F to change from 34.8 to 84.5. *Hence the charge carried by this ion was itself the elementary unit out of which all of the other charges which appeared in the experiment were built up.* The results on another drop which was observed through a much longer time, namely, about four and a half hours, are given in the following table:

n	$4.917 \times n$	Observed Charge	n	$4.917 \times n$	Observed Charge
1	4.917	——	10	49.17	49.41
2	9.834	——	11	54.09	53.91
3	14.75	——	12	59.00	59.12
4	19.66	19.66	13	63.92	63.68
5	24.59	24.60	14	68.84	68.65
6	29.50	29.62	15	73.75	——
7	34.42	34.47	16	78.67	78.34
8	39.34	39.38	17	83.59	83.22
9	44.25	44.42	18	88.51	——

In this table 4.917 is merely a number obtained, precisely as above, from computing the change in the "sum of speeds" produced by the capture of a particular ion, while the column headed "observed charge" gives the successive values of the sum of speeds. It will be seen that during the experiment this drop carried all possible multiples of the elementary charge between 4 and 18, save only 15. *No more exact or more consistent multiple relationship is found in the data which chemists have amassed on the combining powers of the elements, and on which the atomic theory of matter rests, than is found in the above numbers.*

Nearly a thousand different drops have been examined in the manner indicated, some of them being of oil, a non-conductor, some of glycerine, a semi-conductor, some of mercury, a good conductor, and some of other substances, and in every case, without a single exception, the initial charge placed upon the drop by the frictional process, and all of the dozen or more charges which have resulted from the capture by the drop of a larger or smaller number of ions, have been found to be exact mul-

tiples of the smallest charge caught from the air. Some of these drops have started with no charge at all, and one, two, three, four, five and six elementary charges or electrons have been picked up. Others have started with seven or eight units, others with twenty, others with fifty, others with a hundred, others with a hundred and fifty elementary units and have picked up in each case half a dozen elementary charges on either side of the starting point, so that in all oil drops containing every possible number of electrons between one and 150 have been observed and the number of electrons which each drop carried has been accurately counted. It is not found possible to count with certainty the number of electrons in a charge containing more than 200 of them, for the simple reason that the method of measurement used fails to detect the difference between 200 and 201. But it is quite inconceivable that large charges such as are dealt with in the commercial applications of electricity can be built up in an essentially different way from that in which the small charges whose electrons we are able to count are found to be. Furthermore, since it has been definitely proved that an electrical current is nothing but the motion of an electrical charge over or through a conductor, it is evident that the experiments under consideration furnish not only the most direct and convincing of evidence that all electrical charges are built up out of these very units or electrons which we have been dealing with as individuals in these experiments, but that all electrical currents consist merely in the transport of these electrons through the conducting bodies.

The next important question which the above method of experimenting seemed calculated to throw additional light upon is, "What does the ionization of a gas molecule consist in?" Since it is now practically certain that a molecule of air, that is a molecule of nitrogen or oxygen, contains at least a hundred electrons, and possibly very many more, the act of ionization might consist in the knocking out from a single one of these molecules of a large number of electrons, or it might consist in the complete shattering of an atom by some sort of explosive process; or, on the other hand, it might consist merely in the detaching of a single electron from a neutral molecule, thus leaving the molecule essentially the same sort of thing that it was before the ionization took place, save that it has acquired an amount of electricity of the opposite sign equal to that of the charge detached. Some little light can be thrown on this question by studying the observations already presented. In these observations, however, all the changes of charge took place when the drop was falling under gravity, that is, when the electrical field was off, and this for the reason that the chance which a drop has of capturing an ion when the field is off is enormously greater than its chance of catching one when the field is on, since, in the latter case, the electrically charged fragments of an atom, formed by the ionization of a

neutral molecule, are thrown instantly to the plates M and N, their speeds in the field here used being something like five or ten thousand centimeters per second; but, when the field is off, these ions remain in the air between the plates, and, sooner or later, as their number increases, one or more of them comes into contact with a drop and sticks to it. If we look now at the changes which occurred in the experiment recorded, we see that the first change in the time in the field, namely, that from 12.45 to 21.85, represented the advent upon the drop of 2 unit charges, since the 16-second time which is found later in the table was skipped in this catch. All the other changes in the table, save one, namely, that from 34.8 to 16.0, represented the advent of single charges, and this one represents again the advent of a double charge since the 21.9 second speed was here skipped. This indicates that there are probably no ions which have a very large number of units of excess of one kind of electricity upon them, but it gives us no information as to whether the act of ionization consists in the detachment of only one elementary electrical charge from a neutral molecule, or of two or three; for, so long as the changes are occurring when the field is off, it is impossible to distinguish between the capture of a single ion carrying two or three units of charge, and the successive capture of two or three ions each carrying the unit charge.

It was necessary, therefore, to catch the ions at the very instant of their formation, or better, *to catch a molecule in the very act of splitting up into ions.* Accordingly, the experiment was modified as follows. By suitably adjusting the PD between the plates M and N, it was found possible to hold a minute positively charged drop suspended, like Mohammed's coffin, as long as desired between heaven and earth, that is, in this case between M and N, the downward pull of gravity being exactly neutral-

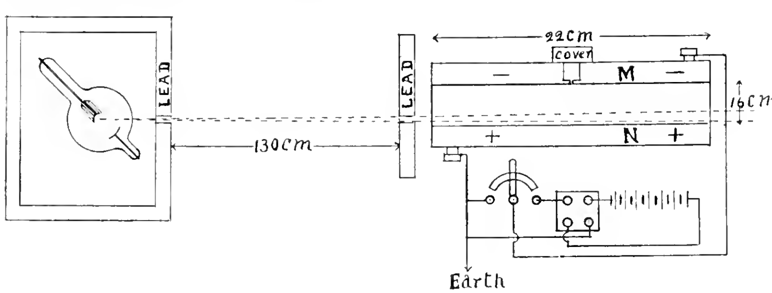


FIG. 3.

ized by the upward pull of the field. Having obtained a drop in this position, there was produced beneath it a sheet of X-ray ionization in the manner shown in Fig. 3, so that when the X-ray bulb was excited, the drop was in a veritable shower of the charged positive residues of the molecules broken up by the X-rays. Now, if two or more electrons were

knocked out of a molecule at once, the residue of the molecule would possess a corresponding number of unit charges, and if this residue were caught by the oil drop, the latter should be seen to jump forward at the instant of capture because of the destruction of the equilibrium between gravity and the electric field; and, furthermore, from the speed which it assumed, as measured by the time which it took to move over a given number of the divisions in the scale of the eye-piece of the observing telescope, the size of the charge of the captured ions could be determined. The experiment was found to be as interesting and as exciting as trout fishing. The star under observation would often stand perfectly still for five, ten, fifteen or even sixty seconds and then suddenly start forward with a speed which was big or little according to the size of the catch and the size of the drop. When we were using large drops, it was found that two or three adjacent molecules were in occasional instances ionized at once, and therefore two or three separate ions were thrown simultaneously upon the drop, but when the drops were very small, we observed in the course of three months about 500 different catches without finding a single one which corresponded with certainty to the advent of an ion carrying more than one elementary electrical charge, and not more than three or four out of the five hundred which were in any way uncertain. This seems to prove conclusively that *the act of ionization by all the types of X-rays and gamma and beta rays of radium which we have been able to try consists in the detachment from a neutral molecule of one single electron.*

So far we have considered merely the proof afforded by the present experiments of the atomic theory of electricity. I have not attempted to tell "what electricity is," but have been content with demonstrating, that whatever it is it always appears as an exact multiple of a definite electrical unit. If you ask me to tell you what it is, I should answer by asking you first to tell me what matter is, and if you responded that matter is that out of which this world and the planets and the stars of this universe are made; that it is something which exists in the form of about 100 different units, or atoms, of relative weights between 1 and 240, which atoms unite together in different ways to form molecules; that the average diameter of one of these atoms is two hundred-millionths of a centimeter, then I should answer, Very well, if you are content with that sort of a definition of matter, I will define electricity for you in a similar way and say that electricity is something which is still more fundamental than your atoms of matter since it is a constituent of every one of these hundred different types of atoms which you have been describing. It is something too, which like matter is built up out of definite units, but it is unlike matter, in that all of these units are exactly alike so far as we are able to determine, save, however, that a marked difference is found between the positive and negative units. For

while the two possess the same charge, the inertia or mass which, so far as we know, is inseparably associated with a positive unit is that of a hydrogen atom, while that inseparably associated with the negative unit is 1/1,760th as much. The negative units, furthermore, or electrons, are so small in volume and are separated from one another within the atom by so large spaces, that one of them can shoot through hundreds and thousands of atoms without hitting anything or doing anything whatever to these atoms. Its diameter is about one one-hundred-thousandth of that of the atom. It is the smallest thing we know anything about so far—probably the smallest thing in existence. Such an enumeration of properties is as near to a definition of electricity as we can come now or are ever likely to be able to come. For, since electricity is the most fundamental thing thus far known to us, it is obviously incapable of definition in terms of anything more fundamental. Its elementary unit, according to the best determination which we have yet been able to make, is 4.80 times 10^{-10} so called electrostatic units, a quantity so small that the electrical charge produced by a single stroke of a cat's back contains billions of them, while the number which courses each second through the filament of a common 16 candle power incandescent lamp is about a billion billion. The electron is thought by many reputable scientists of the present day to be the primordial thing out of which all matter is built up, so that from this point of view the different atoms of ordinary matter are merely different groupings of these fundamental electrical units.

Turning next to the kinetic theory of matter, what have the present experiments to do with it? There are three different ways in which they bring to it powerful support. When these experiments were begun it was anticipated that positively charged ions would be caught by negatively charged oil drops and negatively charged ions by positively charged oil drops, but it had not been predicted that positively charged drops would catch positive ions and negatively charged drops negative ions; for since electrical charges of like sign always repel each other, it might be thought that positive drops would push away positive ions and negative drops negative ions. As a matter of fact, however, positive ions were found to be caught by positive drops about as readily as the negative ions and *vice versa*. The above table shows several catches of this kind. Whence, then, do positive ions obtain the energy which enables them to push themselves up to the surface of a positive drop against the electrical repulsion existing between the two? This energy could not have been obtained from the field, since the capture of the ions occurred when the field was not on. It could not have been obtained from any explosive process which frees the electron from the molecule at the instant of ionization, since in this case, too, ions would have been caught as well, or nearly as well, when the field was on as when

it was off. *Here, then, is an absolutely direct proof that the ion must be endowed with a kinetic energy of agitation which is sufficient to push it up to the surface of the drop against the electrostatic repulsion of the charge already existing on the drop*, and when we remember that an ion is nothing but a molecule containing an unneutralized electrical charge, it will be clear that we have here direct proof that the molecules of the gas are endowed with motion.

Furthermore, it is easy to obtain the energy of this motion, for, if we load up the drop with more and more positive charges, the push which it will exert on positive ions within the gas must become greater and greater, and hence the frequency with which positive ions will be captured from the gas should become less and less. Now this is exactly what was observed to be the case, and, indeed, in one instance, a relatively heavily charged drop was watched for four hours, *during which time it succeeded in picking up but one single ion of its own sign* while the field was off, although it was continually picking up ions of the opposite sign. Its charge was during all this time maintained at about the same value by forcing ions of its own kind upon it *when the field was on*. We had then here a charged drop which exerted just enough repulsion upon the positive ions of the gas to overcome their kinetic energy of agitation when they shot toward it. By knowing the size of the drop and the charge which it carried, it was easy to compute from these two quantities just what this kinetic energy of agitation had to be in this case. It came out within a few per cent. of the value of the kinetic energy of agitation of the molecules as given by the kinetic theory.

But even this evidence is not sufficiently direct to convince a skeptic untrained to follow the computation, simple though it be. Hence a proof was sought which involved no knowledge whatever of either mathematical or physical theory. Fortunately the trail had already been blazed and nothing had to be done but to clear out some of the remaining underbrush which obscured it. It had been discovered as early as 1827 by an English botanist, Brown, that microscopic particles in a liquid keep up incessantly a very minute trembling motion and this phenomenon remained altogether unexplained for more than half a century. At last in 1888 it was suggested by Gouy in France that this trembling motion was probably due to the fact that when a particle is sufficiently small the molecular bombardment which it receives from the molecules surrounding it is not at a given instant exactly the same on opposite sides, and in consequence the particle is pushed first in one direction and then in another by these unbalanced molecular forces. In 1908, Perrin, in Paris, with the aid of a formula deduced by Einstein of Bern, had brought forward quite convincing evidence that this explanation was correct, but Perrin's observations had all been made upon

minute particles suspended in liquids, and liquids are very much less suited to any convincing and accurate test of the kinetic hypothesis than are gases. Apparently the very great advantages of observing minute suspended particles in a gas at very low pressures, where the motions ought to be enormously increased, had not been appreciated, or, at least, had not been utilized, perhaps because the means had not before been at hand for keeping such particles in suspension. Accordingly, the plates *M* and *N*, shown in Fig. 1, with the atomizer attached, were placed inside a large brass cylinder, which could be sealed air tight and exhausted if desired. This apparatus is shown in the photograph on p. 426. When the air was at atmospheric pressure, the smallest particles produced by the aspirator showed clearly the incessant wiggling motions which are called, after their discoverer in liquids, the "Brownian movements." But, when the pressure was reduced to seven or eight millimeters of mercury (about 1/100 of an atmosphere), these motions had increased so enormously in violence that it was difficult to follow the smallest particles as they dashed hither and thither like wrigglers in a water barrel. The reason that reducing the pressure brings out the motion so much more clearly is obviously this: When the oil drop is surrounded by a dense swarm of bombarding molecules, it is like a football in a mêlée of densely packed players who are kicking it on all sides at once, but are unable to send it any appreciable distances. But when it gets out into the open, where the players are scarce, it begins its spectacular flights. Precisely so with the oil drops, and no football game was ever more spectacular or more fascinating than the behavior of one of these oil drops at low pressures. The fact that the motions increase in violence the rarer the gas becomes and the smaller the particles are taken (size being indicated by the speed with which a given particle settles under gravity) is obviously just what ought to happen. There can not then be the slightest doubt that what these oil drops are doing, namely, dancing about violently in all sorts of directions, is precisely what the molecules themselves are doing in a much more excited way for it would be absurd to suppose that the increased speed and the increased distance of the motions as size and mass diminish do not go on after the particles cease to be visible and shrink to molecular dimensions. From the standpoint of a molecule which is darting hither and thither with the speed of a rifle bullet, our dancing oil drops must look like snails crawling about with languorous slowness. But to us they have served their purpose, for they have enabled our minds to see the invisible molecular world doing in a large way just exactly what the oil drops are doing in their small way. They have proved the kinetic theory of matter even to the man on the streets.

But in order literally to pile Ossa upon Pelion in support of this hypothesis, let us next turn to a rigorously quantitative demonstration,

for, while seeing the oil drops dance may satisfy the average man, it will not satisfy the scientist, for he is never content until he has two parallel columns headed, respectively, "calculated" and "observed" values. How shall we set about obtaining such parallel columns? The way was blazed by Einstein in 1905. He showed that if a body like one of our minute oil drops is dancing about in a resisting medium subjected to no forces but those arising from its own energy of agitation, that is, from the bombardment of the surrounding molecules, the mean distance which it will drift in a given time, say ten seconds, from its position at the beginning of this time, can be computed in terms of three factors: (1) its energy of agitation, (2) a resistance factor of the medium, and (3) the length of the time interval through which the drift is observed.[2] But this same quantity can also be easily and directly *observed* in our experiment by simply balancing the force of gravity upon the drop by the force of an electrical field in the manner already described, and then noting over how large a distance *on the average* it wiggles in a given time by virtue of its energy of agitation. In the actual experiments we took, in the case of each drop, the mean of several hundred observations on the distance moved in ten seconds in a vertical direction over a set of horizontal scale divisions placed in the eye-piece of the observing telescope; for Einstein's theory was developed in such a way that the movements to right and left did not need to be considered. The computed and the observed values of this average displacement were in every case in so perfect agreement as to satisfy the most skeptical of scientists that the kinetic theory can successfully meet a rigorous and exacting kind of quantitative test.

But in order to show how free from uncertainties of any sort are the results of this comparison it will be necessary to say just a word more about the theory, for the question is at once raised "how, in computing the theoretical value of the average displacement of the drop, do you obtain the first two of the factors in terms of which this displacement is given, namely, the kinetic energy of agitation of the drop and the resistance factor of the medium?" We obtain a partial answer to this question when we remember that one of the fundamental assumptions of the kinetic theory is that the energy of agitation of a molecule is determined by temperature alone, and is independent of

[2] Einstein's actual equation is $D^2 = 4/3 \cdot E/K \cdot t$, in which D^2 is a quantity obtained by squaring each individual displacement and then taking the mean of these squares, E is the mean kinetic energy of agitation of the drop, K is a resistance factor depending upon both the medium and the drop, and t is the length of the time interval used. If the *average* displacement D is used instead of the average square of the displacements D^2 the correct form of the equation is

$$D = \sqrt{\frac{8}{3\pi}\frac{E}{K}t}.$$

whether the molecule is large or small. Hence, the energy of agitation of our oil drop ought to be exactly the same as that of one of the molecules of the gas which surrounds it. But this is the quantity which we have just determined experimentally, and which, furthermore, can be computed with great precision from the kinetic theory.[3] Hence, we may consider that this quantity is known. The second factor, however, is not known with certainty, except under conditions which may or may not be fulfilled in any experimental work, and herein lies the uncertainty in all preceding attempts like those of Perrin to subject the kinetic theory of Brownian movements to any rigorous experimental test. Fortunately for the present work, however, *this factor does not need to be known* at all. For obviously the resistance which the medium offers to the motion at a given speed of this particular drop though it must be the same whether it is an electrical force, a gravitational force, or a force arising from molecular bombardments which is causing the motion. Consequently all that was necessary for us to do in order to eliminate this resistance factor entirely was first to observe the successive displacements of the *balanced* drop as indicated above and then to destroy the balance and measure how fast the drop moved on the average, both under gravity and under an electrical field of known strength, in precisely the way we had done when we were determining the successive values of the charge carried by the oil drops. From the results of the two experiments we could then eliminate the resistance factor and obtain the average displacement in terms of quantities every one of which was measurable with the greatest precision.[4] Indeed the experimental error in measuring the aver-

[3] The kinetic theory equation is $E = 3/2 \cdot RT/N$ in which E is the mean energy of molecular agitation, R an accurately known gas constant, T the absolute temperature, and N the number of molecules in 2 grams of hydrogen. Although N is not accurately known save through experiments of this sort, it fortunately does not need to be known, as will be shown in the next footnote, for the quantitative test here sought. When the above value of E is substituted in the equation of the last footnote it becomes

$$D = \sqrt{\frac{4}{\pi}\frac{RT}{NK}t}.$$

[4] When the drop is moving down through the medium under the force of gravity, mg, alone, its average velocity v_1 is given by $mg = Kv_1$. The substitution of this value of mg/v_1 in the equation of the footnote on page — gives $e = K/F \cdot (v_1 + v_2)$ and the elimination of K between this equation and that given in the preceding footnote gives

$$D = \sqrt{\frac{4}{\pi}\frac{RT(v_1 + v_2)t}{F(Ne)}}.$$

Since D was of course different for different drops instead of making the comparison between the observed and calculated values of D it was thought preferable to make the comparison in every case between the value of Ne obtained

age displacement was far greater than the uncertainty in any of the factors in terms of which this displacement was computed. *Nevertheless, the final result obtained from the average of 1,735 displacement observations on nine different drops was within less than one fourth of one per cent. of the computed value, and the probable error in this result was but six tenths of one per cent.*

All of these computations relating to the Brownian movements were carried out most skilfully by Dr. Harvey Fletcher. It should be added, too, that in only a portion of the experiments was the observed value of the displacement obtained in precisely the manner indicated above, for it was found that greater accuracy could be obtained in the measurement of this displacement by a slight modification of the method. To make this modification applicable, however, a considerable amount of new and important theoretical work had to be done. This work was most ably and successfully carried out by Dr. Fletcher, and can be found in the August number of the *Physical Review*.

It would seem as though the evidence for the kinetic theory were so overwhelming as to convince every type of skeptic except the one whose mental attitude is that of the farmer who had never seen any save farm-yard animals until he went one day to the circus and stood for some moments looking in amazement at the dromedary; then turning away, he exclaimed, "By gosh, there ain't no such animal." That type of disbeliever I am at a loss to know how to convert.

In conclusion it may be pointed out that not only has it now become possible to prove the correctness of the kinetic theory of matter and the granular theory of electricity, but that, through the results of experiments like the above on the elementary electrical charge, we are now able to determine the exact weight of every atom and every molecule of every known kind of matter, the exact number of molecules in any weight of any substance, the exact value of the kinetic energy of agitation of a molecule, the mean diameter of any kind of molecule, and quite a series of other important physical magnitudes. The first three of these quantities can be found with precisely the degree of accuracy attained in the measurement of the elementary electrical charge, and this is an accuracy of about *one part in a thousand*. Not that I am ready to assert that the value which has been given above possesses that degree of certainty; but rather that we now have a method which is capable of yielding such precision, and the rest is merely a matter of

from this equation and these experiments and the value of Ne obtained from experiments on electrolysis; for Ne is merely the amount of electricity required to separate by electrolysis one gram-equivalent of any substance from a solution. The value of $\sqrt{Ne}$ obtained from the most accurate experiments on the electrolysis of silver is 1.702×10^7 electrostatic units. The mean value of $\sqrt{Ne}$ obtained from 1,735 displacement measurements upon nine different drops was $1,698 \times 10^7$ electrostatic units.

time and of careful work. We are at present engaged not only in checking this value under new sets of conditions, but in redetermining all of the quantities which enter into it. Assuming it as the basis of our computation there are in a cubic centimeter of gas under normal conditions 2.70×10^{19} molecules and the weight of a hydrogen atom is 1.735×10^{-24} grams. These numbers can be made more significant to the ordinary reader with the aid of an illustration. If a million men were to be set counting as fast as they could count, say at the rate of 200 a minute, they could count out the number of molecules in a cubic centimeter in just 252 thousand years if none of them ever stopped to eat, sleep, or die.

"But," says some one, "What of it any way? Does the triumph or defeat of the kinetic theory of matter or the atomic theory of electricity have anything to do with the *practical* problems of the modern world? Is anybody going to be better fed or better clothed because of it?" the answer is, "Within the past seventy-five years—the merest drop in the bucket of recorded time—the conditions of human life on this earth have been completely revolutionized, and that solely because, for the first time in history, man has become interested in considerable numbers, rather than, as heretofore in isolated instances, in patiently and persistently seeking merely to uncover nature's 'useless' secrets, and then, when the inner workings have been laid bare, has in many cases seen a way to put his brain inside the machine and drive it where he would. Every increase then in man's knowledge of the way in which nature works must in the long run increase by just so much man's ability to control nature and to turn her hidden forces to his own account."

UNIVERSITY EDUCATION IN CHINA

By THOMAS T. READ

SAN FRANCISCO, CAL.; FORMERLY PROFESSOR OF METALLURGY, IMPERIAL PEI YANG UNIVERSITY, TIENTSIN, CHINA

ANY account of modern university education in China must necessarily be prefaced by a brief outline of that ancient system of education which has exerted perhaps the most powerful single influence of any that have made themselves felt in the development of a civilization more ancient than any other that now survives. For the forces which are shaping the new educational ideals have roots that strike down into the old, therefore, some consideration must be devoted to the past if we hope to regard the present with clear eyes.

The year 1902 makes an epoch in the educational history of China, for it was signalized by the promulgation of edicts by the Emperor Kuang Hsü which did away with the ancient educational system and created a modern one in its stead. It need scarcely be added that so radical a change was preceded by a period of preparation and followed by a period of adjustment; this latter indeed can scarcely be said to have yet been outgrown. For it is no light task to recast an educational system so vast that it applied to the students of a nation of 350 million people, and so ancient that the academy which stood at its head has an unbroken history of twelve hundred years.

The ancient educational system of China has been described at length by many well-known writers and it will not be profitable to do more here than draw attention to some of its salient features and briefly allude to some popular misconceptions regarding it. Lucidity requires brevity of statement, and the latter precludes the conveying of an accurate idea of any phase of oriental life, which is infinitely varied and complex. I shall attempt to adhere to brevity, in the hope that thereby the reader may not be led too far astray. The old official system was not one of education, but of examination; a modern analogue is perhaps seen in the University of the State of New York. The representatives of the official system were not concerned with the means by which the student obtained his education, their duty being to keep the examination standards so high that the number of successful candidates should not be excessive. Successful candidates were eligible for appointment to official positions, which were limited in number. So, emphasis was laid upon the wrong phase, the making difficult of successful achievement, rather than the easy attainment of an adequate education.

Elementary education was imparted to children in their homes by tutors, or in small private schools, seldom exceeding twenty pupils. There were no schools for girls, but a certain number were taught by members of their own family. In China, as in America, much of the teacher's reward had to be obtained from the dignity and honor of his occupation, for the fees generally paid were small. There were no requirements to be met by the teacher; any one might engage in the occupation, neither was any curriculum nor books prescribed, except by tradition. For the first four or five years the child devoted himself to memorizing the classics, learning to recognize and pronounce the characters, but without knowing their meaning, much as if a modern child were required to commit the Iliad to memory without understanding one word of it. Toward the end of the period the child was given a translation of what he had learned, and taught a little writing and easy composition. In this connection I can scarcely do better than quote Père L. Richard:

> The whole system labored under serious disadvantages, resulted in a considerable waste of time and had little educational value. The memory and imitative powers were marvelously developed, but the mind was not stored with valuable ideas nor trained in precision and accuracy, and there was an utter lack of originality.

Secondary education comprised the study of Chinese literature, and history, the writing of literary essays and stilted verses. When ready the student might go up for examination. The first examination was held yearly in the prefectural cities (which may be roughly likened to county-seats) throughout the empire. The successful candidates received the degree of *hsiu-ts'ai*, and were privileged to attend the second examination held every third year in the provincial capitals. The severity of the competition can be judged from the fact that where from twelve to twenty thousand were examined, only about one hundred would pass. These received the degree of *chü-jên*, and were allowed to attend the examination at Peking, also held once in three years. Here, out of 6,000 candidates about 300 would pass and receive the degree of *chin-shih*. These degrees are often compared to the B.A., M.A. and Ph.D., but the comparison is totally misleading. The Chinese idea of them is shown by the fact that in the modern system the first degree is given grammar-school graduates, the second to high school graduates, and the third upon the completion of professional courses, such as law or engineering. The criteria were skill in the composition of literary essays, in which adherence to prescribed form was desired rather than originality, and purely mechanical proficiency in writing the characters. It will be seen at once that this was a system of elimination rather than of education, and it is not remarkable that the educational results thus obtained were comparatively barren. From this cause, and others too

complex to be discussed here, the intellectual life of China remained upon nearly a dead level, while the western world was advancing from medieval ignorance to twentieth-century enlightenment.

The beginning of modern education in China must be ascribed to missionary influence. As soon as the first missionaries had learned something of the Chinese language and civilization they set about teaching those whom they were able to reach something of western knowledge as a necessary preliminary to evangelical work. Thus missionary bodies were sending out educational pseudopodia throughout the nation which could not be without effect in its mental life. The more astute statesmen engaged for their children foreign tutors, some of whom were later prominent in influencing progress, and many young men were sent abroad to study.

But perhaps the most powerful factor in encouraging the introduction of modern education into China was the Chino-Japanese war of 1895. The lesson of that conflict was a plain one, and the meaning was brought home to his countrymen by Chang Chih-tung in his "*Chuen Hioh Pien*," which, translated into English as "China's Only Hope," is widely known. This epoch-making treatise received the sanction of the emperor and was ordered to be published and circulated throughout the empire. In 1898 the emperor, influenced by Kang Yu-Wei and others, among other radical reforms, ordered the establishment of modern schools in all unused temples. The Empress Dowager's *coup d'état* followed, and soon after the volcanic upheaval of 1900. The lesson of this, added to that of 1895, was painful but convincing. In 1902 the present educational system was established by imperial decree, and in 1905 the old system was similarly abolished.

Chang Chih-tung had strongly urged the advisability of making use of all that the Japanese had done to adapt western culture to oriental needs, and it naturally followed that the scheme for a national system of education was largely modeled after that of Japan, of which a full discussion by H. Foster Bain may be found in an earlier number of this journal. The system now in force may be briefly summarized as follows:

Primary schools (a five-year course) are to be opened everywhere throughout the empire. Higher primary schools (four-year course) are to be established in the district towns the graduates of these receive the *hsiu-ts'ai* degree. Middle schools (five-year course) are to be established in prefectural cities. High schools (often called provincial colleges) (a three-year course) are to be opened in every provincial capital, their graduates receive the degree of *Chü-jên*. A university at Peking completes this scheme, awarding the degree of *Chin-shih*. Advanced technical schools are apparently not to be included in the university, but are separately established. The courses of study to be followed are largely modeled upon Japanese practise, Chang Chih-tung having been

a member of the board which drew up the plan of a national system of education. For example, the course of study prescribed for students of mining is exactly that of the University of Kyoto as given on p. 251 of this journal for March.

The plan of organization for the Imperial University at Peking, as translated by F. Hawkes Pott, is as follows:

1. Faculty of Classics; 10 courses, among which are: (*a*) The Book of Changes; (*b*) The Book of Annals; (*c*) The Book of Poetry; (*d*) Spring and Autumn Annals; (*e*) Rites; (*f*) Confucian Analects, and the Books of Mencius, with commentaries; (*g*) Philosophy.

2. Faculty of Jurisprudence; 2 courses: (*a*) Administration; (*b*) Legislation.

3. Faculty of Arts; 9 courses: (*a*) History of China; (*b*) Universal history; (*c*) General geography; (*d*) Geography of China; (*e*) Geography of England; (*f*) Geography of France; (*g*) Geography of Germany; (*h*) Geography of Russia; (*i*) Geography of Japan.

4. Faculty of Medicine: 2 courses: (*a*) Medicine; (*b*) Pharmacy.

5. Faculty of Science; 6 courses: (*a*) Mathematics; (*b*) Astronomy; (*c*) Physics; (*d*) Chemistry; (*e*) Natural history; (*f*) Geology.

6. Faculty of Agronomy; 4 courses: (*a*) Agriculture; (*b*) Chemistry relating to agriculture; (*c*) Forestry; (*d*) Veterinary science.

7. Faculty of Engineering; 6 courses: (*a*) Civil engineering; (*b*) Mechanical engineering; (*c*) Electrical engineering; (*d*) Architecture; (*e*) Industrial chemistry; (*f*) Mining engineering and metallurgy.

8. Faculty of Commerce; 3 courses: (*a*) Banking and insurance; (*b*) Commerce and transportation; (*c*) Customs.

All these courses are expected to be covered in 3 years, except medicine and law, for which 4 years is allowed. It is allowable for provinces to establish universities, which must conform to this scheme. At the Pei-Yang University, of Chili Province, the courses 2(*a*), 7(*a*), and 7(*f*) have been organized and in other provinces more or less effective universities have been founded. The University at Peking is still in course of development and I do not know the exact stage reached at the date of writing. It is evident that Faculty 1 and Faculty 3 are sops thrown to the former literati of the old school. The best work under this scheme has been done by the Pei-Yang University, referred to again later, which has for some years had an adequate staff of American professors.

So much for the plan; what of its fulfillment? From the viewpoint of the difficulty of the task it is remarkable that so much has already been done, in the face of so many unfavorable circumstances as have developed. The progress in Chihli province is shown by the following figures, taken from the report of the provincial board of education for 1907. If later reports were at hand they would undoubtedly show a

TOTAL ATTENDANCE IN CHIHLI PROVINCE

Year	Number of Students	Increase
1902	2,000	——
1903	8,000	6,000
1904	46,254	38,254
1905	88,000	41,746
1906	135,416	47,416
1907	173,352	37,936

SCHOOLS IN CHIHLI PROVINCE, 1907

Schools	Number of Schools	Number of Teachers	Number of Students
University	1	13	98
Provincial college	1	9	205
Industrial and special (middle grade) schools	13	118	1,612
Industrial and special (lower grade) schools	17	40	446
Upper normal schools	2	46	395
Lower normal schools	98	165	3,448
Middle schools	32	157	2,125
Upper primary schools	220	521	10,599
Lower primary schools	8,675	8,969	148,397
Half-day (or night) classes	121	133	2,971
Girls' schools	121	163	2,625

continuous growth. In all fairness it should be noted that, compared with Chihli, the other provinces would make but a sorry showing, though those which have within their borders large treaty ports, such as Hongkong, Shanghai, Hankow, Ningpo, Amoy and Foochow, have also done well, and the remote province of Ssu-ch'uan, especially so, considering its remote geographical position. It will be perceived that support of the new system is almost proportional to acquaintance with the foreigner, and in developing this support the educational work of the missionaries, both protestant and catholic, has had a preponderating influence, though the material rewards derived from the foreigners' superior knowledge are not unperceived and unappreciated.

A false impression may easily be obtained from figures such as these, by inferring that the results accomplished in these schools are comparable to those of similar foreign schools, which is far from true as yet. This results from a number of causes. Perhaps the chief of these is that the control of the national and provincial educational boards has remained largely in the hands of the officials of the old system, who naturally are rather ineffective in putting the new in force. This has already begun to change for the better, and young men who have studied abroad have been appointed to minor positions on the Peking board, as well as to provincial and local boards. Another drawback is the lack of properly qualified teachers—the pay of teachers in the lower schools is naturally small and the demand for educated Chinese in commercial

positions so great that in many of the lower schools it is almost a case of the blind leading the blind. This, too, is gradually righting itself as the number of graduates of the new system increase. A third disadvantage is the coordinate of the second: the students entering a school are seldom properly prepared to undertake the work prescribed for them. These early defects of adjustment will gradually be outgrown—rapidly outgrown when the control of educational affairs comes into the hands of really competent officials. The hampering effect of these officials is well seen in the case of the Imperial University of Peking (which must not be confused with Peking University, an American Methodist institution). This has, in some sense, been the outgrowth of the Tung-wên-Kuan, established under the scholarly Dr. W. A. P. Martin many years ago. Like an unsuccessful corporation, it has gone through a series of reorganizations and at last seems firmly established with a large staff of foreign and Chinese professors and, with modern buildings in course of erection, should do effective work.

A marked feature of the situation is that the most effective educational work is now being done by schools that are not a regular part of the system and have, therefore, to some degree at least, escaped official control. The number of such institutions is remarkably great, some of them having been in existence before 1902, and others having sprung up to meet real or fancied special needs since that time. Of these easily the first is the Imperial Pei-Yang University at Tientsin, which was founded by Dr. Charles D. Tenney (who had been tutor to the family of H. E. Li Hung-chang) before 1900 and was reorganized by him in 1902, after its destruction in the Boxer outbreak. This remarkably able man, who is now Chinese Secretary to the American Legation in Peking, also organized the school system of the entire province of Chihli, and it is to his effective work that the great growth of modern education in Chihli shown in the preceding table is largely due. The effective work of the Pei-Yang University has been due to its having been almost free from official control during development, at first under the administration of Dr. Tenney and later under Wang Shoh-lien, an equally able Chinese, who, though educated in England for the naval service, has done the most effective work of any Chinese in the development of the new system. When the national and provincial boards of education are composed of men of this calibre, educational progress will be rapid. Graduation from this institution is recognized by American universities as equivalent to attaining the B.S. degree; it thus enjoys the unique distinction of being the only Chinese institution of learning whose degree (Chin-shih) is recognized abroad. It should be added here that this, and all other schools, can not grant a degree *per se*: the school devotes itself to the work of instruction; degrees are granted upon examination by an official board created for the purpose. This school is now practically a part of the regular system.

Among other irregular institutions is the Shansi University at Tai-yuen-fu, now under foreign control, but which will soon be turned over to the provincial government. This is doing effective work, as is the Tongshan Engineering College, of which S. S. Yung, a graduate of the University of California, is president. This school is under the control of the Board of Posts and Communications. Nan-Yang College at Shanghai, Nanking University at Nanking, and a host of others make up a list which it would take too long to enumerate, and as the relationships of many of them are somewhat vague it would in many cases be difficult to decide whether a given school were really a part of the regular system or not. Among these are five naval colleges already established, and six additional ones proposed, numerous medical schools, for training surgeons for the army and navy, training school for officials, and other special schools. In many of these, in order to secure students, the tuition, books, and board were not only free, but the students actually received a stipend of a few dollars per month. The instruction in many of the schools was at first of little account, and they were derisively termed *chih fan hsueh t'ang* ("eat-food schools"). These also are now much improved in effectiveness, and the ability of Chinese physicians, notably Dr. Wu Lien-teh, formerly vice-director of one of these schools, was conclusively shown in the handling of the outbreak of the plague in northern China in the autumn of 1910.

From this brief review it will be seen that university work in China lies in the future rather than the present, as the most advanced work at present, that of the Pei-Yang University, is little better than of college grade, while this and all the other advanced secondary schools are largely technical in character. University work, in the ordinary sense of the word, is not yet being done, the demand for vocationally trained men being greatest. The difficulties of higher secondary educational work are numerous, among them the necessity of conducting it in some foreign language, usually English. This is not due, as might be at first supposed, to the necessity of employing foreign instructors, but is rather because, for a number of reasons which would require too lengthy explanation, it is not practicable to translate text-books of university grade into Chinese; to teach the students the foreign language being at once easier and better. This is one of the problems of the future; foreign instructors are expensive; the use of foreign language by native instructors will present many difficulties, while those encountered in the preparation of advanced text-books in the Chinese language are almost insuperable. Another problem is the insurgent spirit of the student body in many institutions. Though a proverb similar to that regarding the teaching of one's grandmother to suck eggs is well known in China, its full force is not always appreciated by the students, though in extenuation of their oftentimes insubordinate conduct it must be ad-

mitted that the administration and even the instruction in the new schools is sometimes woefully ineffective. As in Russia, the student body throughout the empire is filled with a revolutionary spirit and tinged with idealism. But it must not be inferred from this that the outlook is other than hopeful, for to one who realizes the strength of Chinese conservatism the progress already made is tremendous and the possibilities of the future illimitable.

Many will ask why the introduction of modern education in Japan was so much more rapid than in China, a proverbially scholarly nation. The reason is just that in Japan there was no old system to clear away; the nation began with a clean slate and an immense desire to learn, while in China the value of modern education was but tardily recognized and the new had to establish itself in the face of the opposition of the old. Some of the men who have had a prominent part in this have already been mentioned, but I can not forbear to speak of the great body of other Americans who are, far in excess of all other nationalities, taking a prominent part in the present work. Of the educational work under missionary auspices that of the Jesuit fathers was early prominent and is still important. Missionary bodies of every nationality are carrying on important educational work, chiefly primary, though secondary work is not neglected, as the American Methodist Peking University, the American Episcopal St. John's College at Shanghai, the Jesuit College at Sicawei, the English Episcopal Anglo-Chinese College at Tientsin, the Christian College at Canton, the Soochow University, the Union College at Wei-hsien in Shantung, and many others, serve to testify. These, like denominational colleges in America, held a dominant position at first, and like them can not hope to long hold a leading position in a national system of education. In these, as in the secular schools, Americans are most prominent and, paraphrasing the epigram as to the songs of a country, it seems clear that, with American influences predominating in the schools of China, the future development of that country, now in the throes of political readjustment, can not escape being profoundly influenced by American ideals.

PRECESSION: AND THE PYRAMIDS

By Dr. PERCIVAL LOWELL

BOSTON, MASS.

TO be told that five thousand years ago the Southern Cross could have been seen by one standing where London stands to-day would certainly cause most people surprise. Nevertheless such was the fact. That celestial asterism to which persons who have not seen it look forward as to one of the revelations incident to voyages into the tropics and then, on beholding it, feel egregiously duped, needed then no far travel to disclose. The sad disillusioning caused by its rising could have been enjoyed without leaving home. For 3000 B.C. its center-void apology for the real thing might have been observed above the outline of the South Downs at midnight at the proper season of the year by a star-gazer at the then mute and inglorious Greenwich.

If amazed at the apparition our tourist thus transported back in time turned to get his bearings from the north, not less astonished would he be to discover his old friend the pole-star unaccountably gone. Even the learned might experience a shock. Certainly to those who drink in their star-knowledge through the medium of the Dipper would it prove disconcerting to find Polaris adrift in the sky. Its fixity fled, our cynosure would indeed be difficult to detect. Just as mediocrity exalted by office sinks into plucked insignificance once its insignia are removed. Nor would he find the solace of familiarity anywhere else. For such upsettings of fundamental fact would confront him everywhere. The whole firmament would appear to be turned topsy turvy could we suddenly be canopied by the heavens of those departed days. All the constellations would seem askew even if he succeeded in making them out. Nothing new under the sun! perhaps; but a very different state of things under the midnight stars.

Such a thorough change in outlook upon the universe is certainly no mean event and serves to point the importance of a subject in astronomy well worthy of engaging general attention, the more so that it is intimately associated with man. For this revolution in the sky is brought about by what is called the precession of the equinoxes. The name is due to what first disclosed the action. Primitive man framed his calendar by the stars. Not having the benefit of an Old Farmer's Almanac with its superannuated tillage advice, the husbandman then judged his seedtime and harvest by the constellations that rose in the morning just before the sun. How long he placed implicit confidence in such chro-

nology after it became out of date we can but surmise. For that the stars and the seasons which they ruled did not continue to agree must have been early evident to the astronomer-priests who made a study of the two the basis of their calendar and of all the functions, aratral and religious, appertaining to it. So that the stellar springtime of one year was not the springtime of the next. That the zodiacal constellations were continually moving forward to meet the sun in his yearly round of the sky could hardly, one would have supposed, have escaped the observation of antiquity. Yet we find no mention of the fact; not so much as an ascription of the incongruity to the errors of predecessors.

To Hipparchus is due the honor of its discovery; a detection brought about in this wise. Besides watching the heliacal risings of the stars the ancients had another way of determining the date of the vernal equinox: this was by noting by the gnomon of a sun-dial the times when the shadows cast by the sun at noon were longest or shortest. This gave them the dates of the solstices. Hipparchus by comparing his own observations with those that had preceded him—on Spica, chiefly—found that the two methods did not agree but that the equinox as set by the sun stepped forward to meet the stars by about twenty minutes each year. As he perceived that while the longitudes of all the stars were thus changing, their latitudes remained the same, he concluded with the astuteness of genius that it was the equator that was moving, not the ecliptic; that is, the earth's tilt was shifting not the sun's.

The merit of Hipparchus in the matter was two-fold: the ability to discover the thing and then the courage to proclaim it. For in the good old times men were no quicker to recognize advance than they are to-day and were just as possessed to denounce it. In consequence Hipparchus's discovery suffered the usual fate of new truths. Some astronomers disputed his facts, others explained them away as an oscillation merely, while yet others simply ignored them. In spite of which mundane anathema the slow movement of the equinoxes went obstinately on.

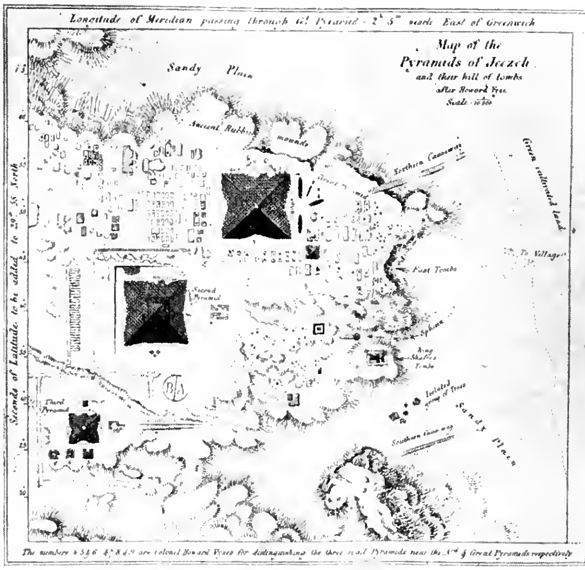
This mighty revolution of the equinoxial points by which spring opens twenty minutes earlier each year Hipparchus was not able to explain. He noted the fact, which was a feat remarkable enough, considering his means. Indeed, he probably never tried to penetrate further into the mystery. The Greeks were better geometers and more discerning reasoners than we were brought up at school to believe, but in astronomical matters a great gulf lies between them and modern thought. They never conceived the principle of universal gravitation. Failing this, it is no wonder they never imagined to what precession could be due. For the realization of this result of gravity is a much more advanced step in celestial mechanics than the accounting for the circuit by the planets of the sun.

Not wholly easy at first of comprehension, appreciation of the prin-

ciple which underlies it will be found well to repay the trouble it costs. For to master it is to put one's self in possession of a celestial time-piece one hour of which is 25,700 years and whose minute hand traces out the lapse of centuries upon the dial of the sky. Not only as a clock is it a possibility, but as we shall see it has been actually so used unconsciously by man in days gone by, and his readings of it recorded in lithographs still legible to-day.

To understand its working we must in thought get off the earth and see that body from without. We should then perceive our globe as a mammoth top spinning in the sky as it moves along in its orbit. The spin gives us our days, and as the equator is tilted to the path the pull of the sun is all the time trying to bring the one to coincidence with the other. If the earth were perfectly round there would be nothing for the sun to grasp and the spin would remain unchanged both in amount and in direction. The earth, however, is not round, but spheroidal, bulging at the equator. There is thus a handle, two handles in fact, which may be used for turning it. Now suppose the earth in the position of its summer solstice when its axis is tilted away from the sun in a plane containing the sun and a perpendicular to its orbit. The attraction of the sun tends to rotate it in this plane. Meanwhile the earth is spinning round its own polar axis at right angles to that direction. We have then to compound two spins about axes perpendicular to one another. Curious as it may seem, the result is not to pull the bulge down into the orbit plane, but to make it back bodily along the ecliptic. It is as if the earth resented the sun's attempt to right it and with almost human perversity went the other way. Indeed one may feel the obstinacy of the thing by appropriately pressing on a gyroscope, when instead of yielding it will promptly buck against you with a force suggestive of intent. The greater your shove the faster its opposing speed. Now with the earth the pull of the sun is feeble compared with the great moment of momentum of the earth, and in consequence the motion of the earth's pole is most leisurely. The backing of the equinoxes to meet the sun is but 50″.23 a year and the time it takes to complete the circuit of the zodiac 25,700 years.

The figure of the earth exposing it to such action, any body may set it spinning and all do. The amount and direction of the spin depend on the position of the disturber. Because the greatest, by precession is usually meant the luni-solar precession, caused by the combined action of the sun and moon. In this the moon is about two and one eighth times as effective as the sun in spite of its relative insignificance because of being so much nearer. The amount of the precession depends among other factors upon the cosine of the obliquity of the ecliptic. The greater the obliquity, therefore, the less the precession. At the present moment the obliquity is diminishing and the precession increasing. This will continue to be the case for several thousand years.



MAP OF THE PYRAMIDS OF JEEZEH.

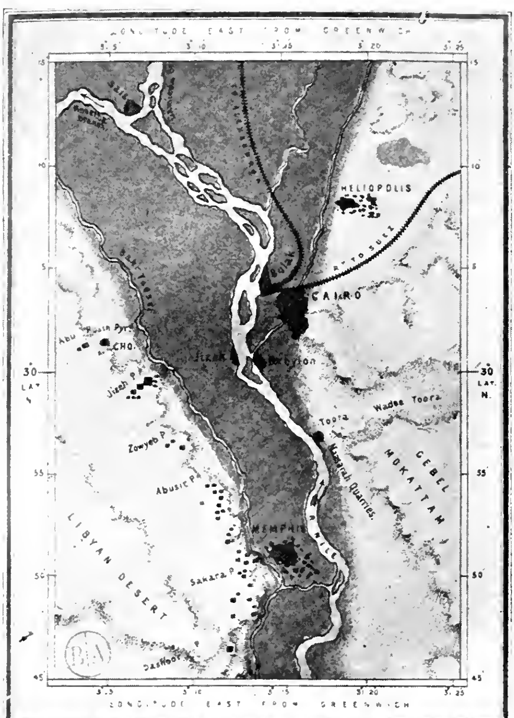
Besides this precession another or, more properly speaking, several others are produced indirectly by the action of the several planets upon the plane of the ecliptic. As these bodies are out of the plane themselves their action pulls the earth out of her orbital plane, causing a change in the obliquity of the ecliptic. There is in consequence a slow alteration in the place of the pole of the ecliptic and this results in a movement of the equator other than what the sun and moon produce. It is known as the planetary precession. Chiefly by such round-about process do the planets make themselves precessionally felt. For all of them, even Jupiter, are relatively too small and too distant to have their direct pull upon the earth's equatorial ring of any account. The direct precession due to Jupiter is only about 0″.0001 a year and that caused by any other planet much less.

As all the planets are concerned in the work, and as they are all pulling different ways, the combined effect is not regular in either extent or duration, although there is a general swing to and fro of the ecliptic as the result. Its periods are much longer than the luni-solar precession. Thus, according to Leverrier, the one now going on had its maximum effect about 10,000 years ago and the next will be 35,000 years hence. This may be taken as about the mean swing; which shows that it is thrice that of the precession of the equinoxes properly so called. It is so combined with the latter, however, that though quite extensive in itself, amounting to more than 4°, it can never change the tilt of the ecliptic to the equator by more than 1°, one third on either side, so that our seasons

can never differ greatly from what we know them now. They can neither be materially accentuated nor proportionately reduced.

Though the obliquity of the ecliptic is oscillatory, the motion of the ecliptic pole keeps persistently, though unsteadily, on always in the same sense. Its wanderings trace out an elliptic spiral which never returns into itself. Its vagaries resemble as much as anything an unevenly bent spring carelessly coiled about a mid-position from which it never far departs.

Meanwhile our own pole pursues its relatively sedate march around the other, permitting its position to be calculated at any past epoch not too remote. We can plot its path and thus see near which stars it passed, stars which had the earthly distinction once upon a time of being our cynosure. In this manner we discover that 4,690 years ago, or in 2780 B. C., the pole passed within 3′ of arc of the star α Draconis. Practically the star was the pole, and it was the last bright star the pole approached before reaching Polaris. In the time of Hipparchus, 140 B.C., the pole lay undistinguished in a waste region of the sky. α of the dragon is now a star between the second and third magnitudes, but there is evidence to show that in ancient times it was brighter. It must



MAP OF THE NORTHERN PART OF THE ANCIENT PYRAMID FIELD IN EGYPT.

therefore have been a fine pole-star in its day, both because of its nearness to the pole and because of its own intrinsic brilliancy.

Of interest as this is from an academic standpoint, it becomes impressive when we learn that this prophecy about the past was contemporaneously verified and witnessed, as unconsciously as it was conclusively.

Not only was α Draconis once the pole-star, but it was actually so seen of men who have left us record of the fact. And this, too, without the slightest idea that they were dating history, and in the most dramatic manner possible. Not by carved or written inscription, not by oral tradition handed down by word of mouth, was this accomplished, but in a way at once more silent yet more sure—mutely embodied in the very core and being of a building the grandest ever erected by man. The Great Pyramid, the pyramid of Cheops, tells us this in stones that bear no character at all and only astronomy can read.

Herodotus, the "Father of History"—known also as the father of lies in what may be called the Ananias Club sense, for we are now learning that what he narrated, though seemingly unbelievable, usually turns out to be true—informs us that when he was in Egypt he was told by the priests that a long time before certain peoples had come down from the north, possessed themselves of the Egyptian power and so far affected the mind of the then King Cheops or Suphis that he forsook the Egyptian religion, caused all the temples to be closed and set to work under the stranger's direction to build a huge pyramid of stone.

The same veracious if also voracious historian goes on to say "that 100,000 men were employed for twenty years in building it; that Cheops was succeeded by his brother, Chephren who followed his pyramidal example; and that by the space of one hundred and six years all the temples of the kingdom were closed." In consequence the pious Egyptians deprived of their natural religious vents "detested the memory of these kings"; as they may well have done for other than religious motives, seeing that they were employed at forced labor on such a scale for such a length of time.

Manetho, who confirms the royal apostasy mentioned by Herodotus, gives us to suppose that we have here an invasion of the shepherd kings about the time of Abraham. Their force seems to have been intellectual, as they overturned the whole Egyptian system of things, he says, without a battle. So that they were probably Chaldeans, and the pyramids which they caused the king and his successors to construct were not Egyptian monuments at all, but embodiments of a foreign cult peculiarly distasteful to the followers of Isis and Osiris. Indeed, as we shall presently see, they were neither Egyptian nor monuments.

What they were not is plain; what they were has best been deciphered by Proctor, who has shown well nigh conclusively that their purpose was

astrologic. That they were astronomic constructions they themselves reveal, and the only rational explanation of the power the strangers gained over the mind of the king lies in the astrologic art the Chaldeans are known to have possessed, and which is also known to have been eagerly sought after by all the peoples of the east.

Both without and within they testify to a very heavenly regard on the part of their builders. In the first place their situation is expressive. They stand within a mile of the thirtieth parallel of latitude and undoubtedly were only prevented from standing nearer that astronomic line by the fact that the plateau shelf on which they were erected here falls abruptly to the plain. At this point on the earth the north pole is 30° high, and thirty degrees has this commendation to geometers, which the pyramid builders emphatically were, that a perpendicular from it to the line of sight is at that elevation exactly half as long as the line of sight itself.

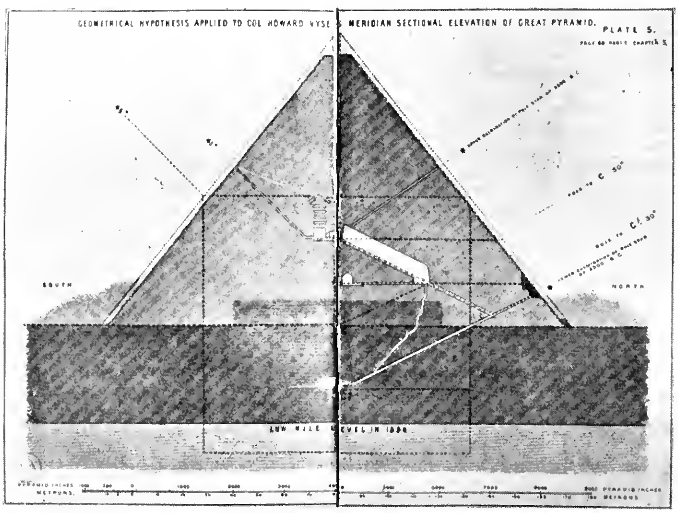
In the next place the base of the building is four-square, its sides being oriented to the compass points with surprising accuracy. Just as Christian churches face the east, that is Jerusalem, and Mohammedan ones Mecca, so the pyramids faced the north. Here then we have surmise of both religion and astronomy, to wit astrology, embodied in the mere outward aspect of these constructions.

This is, however, as nothing to what the interior reveals. Upon the north face of the Great Pyramid a passage opens, descending for 350 feet through tiers of stone at first, then through the solid rock. This passage points to the north within 4′ or 5′ in azimuth, is perfectly straight and is inclined to the horizontal at an angle of 26° 26′. The long straight hole suggests that it was used for looking at a star, for down it a bright star might even be seen by day. Its direction, moreover, hints that the pole-star was the one in question. Now the latitude of the pyramid is 29° 58′ 51″. The subterranean tube, therefore, does not look directly at the pole: but when we take refraction into account we find that it would look exactly at a star distant 3° 34′ from the pole when that star was at its lower culmination, that is, passing the meridian directly south of the pole.

Now if in latitude 30°, a man wished to observe the north or south passage of a circumpolar star, in order, for example, to ascertain true north, the best means of doing so would be to dig a subterranean passage-way pointing approximately northward and then mark through it when the star ceased to rise or sink; and since either culmination would suit him he would naturally choose that one in which the slant of his tunnel would be the least, both because he could dig it easier and because he could descend it best. An incline of twenty-six degrees is distinctly preferable to one of thirty-four. Now 645 years before or after the date when α Draconis was approximately upon the pole, it

was 3° 34′ distant from it; that is, in B.C. 3430 or B.C. 2140. The passage, then, chronicles the time when the pyramid was built—with a seeming choice of alternatives. But the nearer of these is negatived by what we know of Egyptian history and we are thus left with the other, that of B.C. 3430, as the date of the pyramid's construction. The pyramid thus dates itself astronomically, which is the first remarkable thing about it.

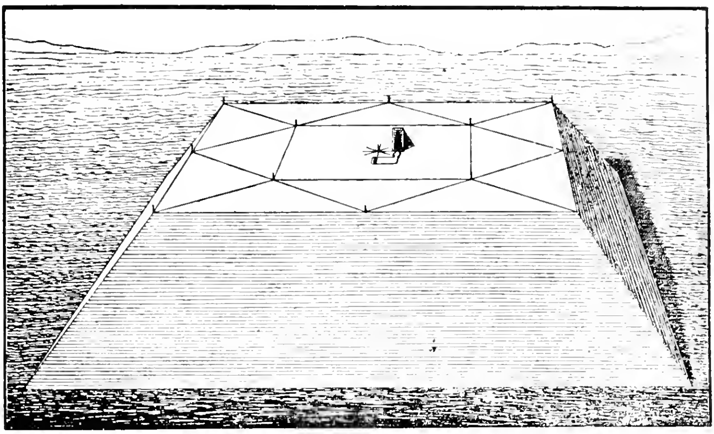
It is to be noticed that astronomy here furnishes Egyptology with a fixed epoch from which to go forward or back. We are not here dealing with conjectures as to when a certain king or dynasty can be made



Geometrical Hypothesis applied to Colonel Howard Vyse's Meridian Sectional Elevation of the Great Pyramid.

to fit into a general chronologic scheme by the relics it has left us of itself. Calculations from known astronomic data can tell to an exactness gauged only by the size of the opening of the passage as seen from below precisely when the pyramid was built with only the choice above described. To deny which would but argue a lack of appreciation of physical science. For that such a pointing can be but the sport of chance, the whole structure of the pyramid emphatically denies.

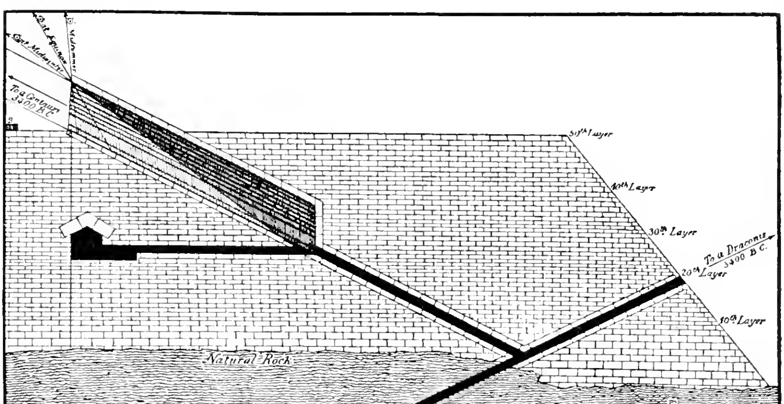
The Great Pyramid was in fact a great observatory; the most superb one ever erected. The building is the most mammoth in the world, and it had for telescopes something whose size has not yet been exceeded. This something which did those old astronomers for instrument was the Grand Gallery. As its name implies this was a stone gallery of imposing proportions set on an incline of 26° 17′ in the very heart of the structure and pointing south. It is approached by the



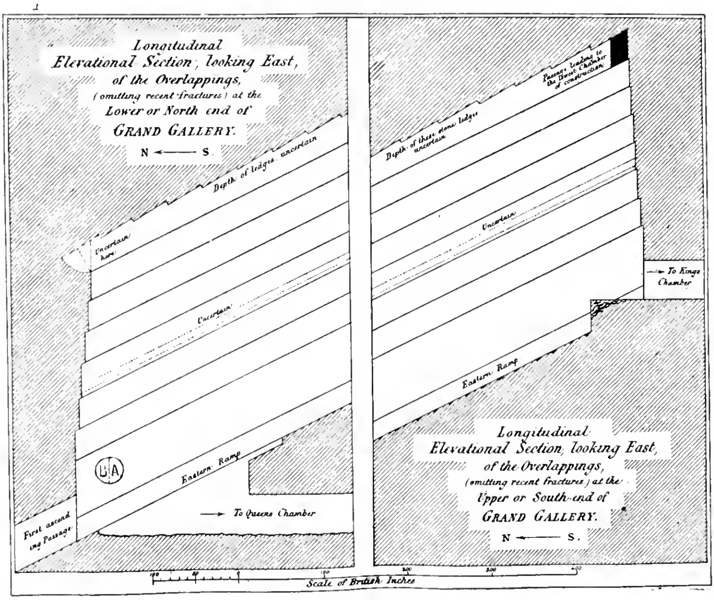
THE GREAT PYRAMID OBSERVATORY.

descending passage which looked at the pole-star and thence by an ascending one at about the same angle which opens into it. It is one hundred and fifty-seven feet long, twenty-eight feet high and about eight feet wide. Along the center of its floor a smooth stone flagging ascends, flanked on either side by raised curbs or ramps half as wide each as the central paved pit. These curbs are not continuous but are cut at approximately equal intervals of about five and a half feet by notches with vertical edges. There is no doubt that these were for the insertion of benches, as the notches tally on opposite sides. At about sixteen feet from the bottom the central incline stops in a vertical wall which descends to a horizontal pavement, giving entrance to the corridor which runs to the Queen's apartment.

The roof of the gallery is everywhere smaller than the floor, so that



VERTICAL SECTION OF THE GREAT PYRAMID, SHOWING THE ASCENDING AND DESCENDING PASSAGES, GRAND GALLERY AND QUEEN'S CHAMBER.



LONGITUDINAL SECTIONS OF THE GRAND GALLERY.

it overhangs the bottom about one foot eight inches on three sides, 39.5 inches at its southern top. The stones on the sides are carefully set in tiers, the sides themselves being oriented to the compass points. Its exact dimensions which we shall find telltale are:

	Inches
Inclined length of floor	1,815.6
Same produced to south walk	1,883.0
Height	339.0

It is now of course walled in by stone on every side, but in the day of its use it undoubtedly stood open at the top, the horizontal passage in which it now ends at the summit having been the beginning of the platform of the whole pyramid, at that height. No records tell us this; our information comes from the gallery itself. Now if we calculate the angle from the vertical which the end of the cornice makes with the upper end of the floor we shall find it 6° (6° 20′). Remember that the gallery faces due south, so far as the builders could place it, that the latitude was 30° (29° 58′ 51″) and that the obliquity of the ecliptic was then 24° (24° 4′). Now subtract the second angle from the first to get the altitude of the sun at the summer solstice, and we have 6°. Consequently at that season the shadow of the gallery roof would just strike the south end of the gallery floor. A curious astronomic coincidence, you say. But go a little further. Let us calculate the angle from this same coping down to the end of the central incline on the

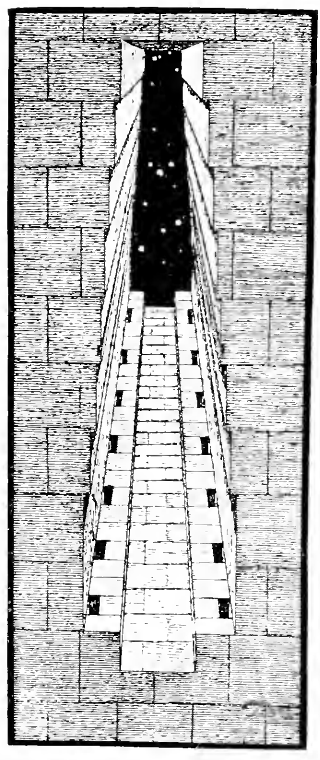
gallery floor. It comes out 36° 10′. Now at the winter solstice the sun was 30° + 24° from the zenith or 54°, that is, 36° from the horizon, the angle just found. In midwinter then the sun shone just to the bottom of the effective gallery, as at mid-summer it had marked its top. Between these two extremes the shadow must always fall. Thus the gallery's floor exactly included every possible position of the sun's shadow at noon from the year's beginning to its end. We thus reach this remarkable result that the gallery was a gigantic gnomon or sun-dial telling, not like ordinary sun-dials the hour of the day, but on a more impressive scale, the seasons of the year.

That the gallery itself extends below the point where the central incline drops vertically to permit of entrance to the Queen's Tomb with its ramps notched, as above, does not vitiate the deduction, for observers could not generally be placed on benches with their legs hanging down, however they might be so located on emergency. The recognition of this function of the gallery is not new, being, I believe, due to Proctor, but the exact coincidence of the limits of the effective gallery with those of the sun has, to my knowledge, never been pointed out.

Such, then, was the use of the entering passage, and such the design of the Great Gallery. Grand as was communion there with the sky by day, it must have been sublime at night—alone with the stars in the heart of that superb monument of stone. About the year B.C. 3430 it was further heightened by a spectacle which could not be witnessed now. Calculation shows that the great star α Centauri, the brightest and nearest to us of all the fixed stars, shone then at its upper culmination night after night down the hushed and polished vault of the Great Gallery.

α Centauri now hardly peeps above the pyramid's horizon at its highest, and in a few more years will never rise there at all until, thousands of years hence, the pole in its majestic precessional march raises it into view once more.

In a peculiar sense the pyramid was the man for whose use it was built. Primarily its purpose was to cast his horoscope through life, and then when his days were ended it became his tomb. He was



THE GRAND GALLERY.
VERTICAL SECTION THROUGH

buried in its interior. What had been its astrologic platform on top was continued on to an apex and then the whole structure sealed up, to remain, so it was fondly hoped, inviolate through time.

One reflection well worth our thought the pyramids suggest: the enduring character of the past beside the ephemeralness of our day. We build for the moment; they built monumentally. True we have printing which they had not. But libraries are not lasting. Fire accidental or purposive has destroyed the greater part of the learning of the far past and promises to do so with what we write now; and what escapes the fire mold may claim. Only that idea which is materially most effectively clothed can withstand for long the gnawing disintegration of time. The astronomic thought of the pyramid-builders lives on to-day; where will record of ours be, I wonder, five thousand years hence. We may be quoted indeed with ever-increasing inaccuracy of transcription, but the star-priests of α Draconis's time speak in their own words still.

To us Cheops is hardly more than a name; long since his ashes were scattered to the winds; but the building those old Chaldean soothsayers constructed for him remains, not only to-day the grandest monument of man but the oldest and most significant astronomical observatory the world has ever had.

NEW YORK'S TEN THOUSAND

By WILLIAM J. ROE
NEWBURGH, N. Y.

FOR many years periodicals which make a point of entertaining timeliness have printed articles concerning the police force of New York City. Very few of these have been flattering, although at times, especially when some novelty of legislation has been inaugurated, or a new and more or less distinguished chief of the department entered upon his duties, they have expressed a guarded hopefulness of better things. But for reasons that to the initiated are sufficiently clear, few of these expectations have been realized; and of late the articles have been either in the nature of reminiscences, or what has come to be called "muck-raking."

The object of this paper is neither to relate incidents—historical or scandalous—and such interest as it may have will be solely of that sort which citizens having the welfare of the city at heart may take in whatever tends towards the establishment and maintenance of permanent good government.

Under our federal system republican principles of representative government are in full force, not only among and between the states, but in counties, townships, villages and school districts. In all these local interests are directed by local authority, representative government being the prevailing rule. Outside of the large cities authority touches the average citizen but lightly; in fact, in most rural neighborhoods the presence and pressure of legality is felt only once a year when the collector of taxes makes his official existence manifest, or when occasionally some local issue (in this state usually a question of "wet or dry") arises.

But in New York City, a very different condition of things exists. Here a constant need for the law's efficient maintenance surrounds and presses upon both householder and visitor. Rules and regulations, unknown because unnecessary in smaller or thinly settled communities, are here imperative. Questions of common rights, or mutual duties, of order, of sanitation, of the preservation of equality in some directions and of the equitable permission of privilege in others; these, and many more problems in utmost perplexity continually arise, demanding not only cheerful acquiescence from the law-abiding, but the constant strain of that eternal vigilance which is the price that must be paid for liberty.

While it would be uncivil and to a great extent misleading, and might be considered unpatriotic to assert that our republican form of government, so admirable in the nation at large, has in practise broken down in the great cities, calling attention to manifest truth can harm no one, however sensitive; to a very considerable extent New York City is denied one of the first essentials of republicanism—home rule; in many respects it is governed as a conquered province from Albany. Perhaps some—or even all—of these denials are inevitable; at all events they are legal, and the good citizen is bound to submit gracefully, however much he may deplore the fact that some of the most cherished guarantees of democracy are absent in metropolitan life. He may console himself with the knowledge that legislation entirely appropriate to rural neighborhoods is utterly impracticable as applied to a city of nearly five million inhabitants, closely, and in sections stiflingly clustered, of many races and faiths and of countless diversities of habit. Not only do the laws by which the metropolis is governed emanate largely from sources exterior to itself, but these laws are continually changing. Unlike the national administration, which is in essentials simple and comparatively stable, that of the city is extremely complex, the laws which it is the duty of the police to enforce being not only intricate, but are being tampered with and altered continually. The conditions in these respects that have prevailed and still do prevail are sufficiently perplexing to confuse and demoralize almost any body of men on earth; that they have not demoralized further than they have the police force is greatly creditable to their self-control, sagacity and respect for constituted authority.

In order to understand the exact nature of the very radical change which it is my purpose to outline, something in the way of both comparison and contrast between the national and civic administration may well be considered. Especially ought these comparisons and contrasts to be clearly understood between the regular army (the police of the nation) and the police force, which may be considered as the army of the city.

The civilization of the western world, the Teutonic race having been always in the van of progress, has achieved at least one lesson perfectly learned—the deplorable results of irresponsible power and the necessity for those limitations upon the will of an executive to be summed up in one comprehensive phrase—the law. In America, as we know, the limitations have for their source a written constitution, to be interpreted by an unprejudiced judiciary, and directed by congress.

But in the course of the broadening of freedom this curious paradox is disclosed, that while parliaments and congresses have grown continually more and more mindful of the people's will, the strength of the executive of that will has been continually enlarged. In the

days of the Tudors and Stuarts, the English people, slavishly submissive to the caprices and excesses of monarchy, always stubbornly refused to countenance a standing army. In the early wars in which England was engaged it was seldom that her land forces were better than armed mobs; and until Cromwell trained his Ironsides, hardly anything that at the present day would be called discipline was known. Now in America the president possesses powers for action greatly exceeding those of any limited monarch, and almost equaling those of an oriental despot. He is not only absolute within limits prescribed by civil law, but he is commander-in-chief of the army and navy, and as such may in certain emergencies suspend or annul the functions of congress and the courts. This is not only theoretical, it was proved during the war-between-the-states to be preeminently practical, notably in the instance of the emancipation of the slaves. The possession of such masterful powers indicates, not at all any peril of "imperialism," so called, but rather an expression of the cordial consent of an enlightened and free people, and the certainty that the law may safely permit a temporary suspension of its own functions, confident that—the danger overpast—these will be resumed without impairment of liberty.

The strong arm of the president of the United States for the enforcement of the laws of the land is the regular army. Note with what remarkable foresight our system was planned to avert the danger that so affrighted our British ancestors. The ordinary civil processes for the quelling of disorder—the sheriff and his posse, constables, police—failing, the state militia are called out; and these all having proved ineffectual, constitutionally recourse is had to the authority of the president and the army. And this force is at once the most masterful and the least domineering. Every now and then—some "radical" having urged more vehemently than ordinary "government ownership of railways," the return outcry voices the fear that the votes of so many employees would be utilized by the chief magistrate "to perpetuate his power." But while there may be a possibility that such fears are genuine, who for a moment associates the idea of politics with an army man? Often in the course of our history some successful general has been seized upon by a political party as an available candidate for the highest office. Almost half our presidents and presidential candidates have been more or less military men. Usually they have been politicians in inverse proportion to their military ability, for the most part perhaps, "Good men weighing so and so many pounds."

Note upon what inflexible principles the army is decreed, constituted, manned, officered and governed. It emanates directly from the people, the people's representatives, by authority and direction of the constitution, permitting it to exist only from congress to congress.

But once authorized, or the authorization renewed by renewed appropriations, congress is almost invariably wise enough to refrain from further interference. The art of war is recognized as a *metier,* a trade, the most exacting and absorbing of professions, demanding not only high technical skill, but for the utmost efficiency power completely within itself, the capacity to act as a unit. So governing the regular force is left to those competent from training and experience to guide it. Watched by a civilian secretary of war, the elements in control are the acts of congress, the articles-of-war, the rules and regulations of the service, and the individual authority, strictly limited and defined, of the officers from the chief-of-staff to the subalterns. The office of a man in commission is for life or during "good behavior"; ordinarily he can be removed only upon specific charges, and these must be proved before a duly constituted court-martial; in any event he may claim the protection of congress. But always these salient facts stand out unqualified—the entire separation of the civil from the military functions—the just jealousy and dominance of the civil power, the freedom within limits of the military, and also the clear line of demarcation between the legislative and judicial functions and those purely and properly executive.

The police force of the city of New York has some points of resemblance to the regular army, and many more where the analogy has no application. A policeman is in fact in hardly any sense a soldier; he is better to be described as a civilian, suitably armed, and clothed with powers and responsibilities relating primarily to the preservation of the peace, and incidentally to the detection of crime, the capture of criminals, the enforcement of the law and the arrest of violators of the law. This force, unlike the army, is the creation almost of yesterday; principles virtually settled as to the national body of armed men, have not as yet taken definite and coherent shape with them. The blundering incident to everything new, raw and tentative, may be traced in the numerous experiments made in compliance with enactments of the state legislature. These have been due mainly to party policy, but sometimes to well-meant ignorance (often miscalled "reform") and sometimes, it is to be feared, to deliberate or even immoral scheming. Sometimes a board of commissioners, all of one party, has controlled the department: sometimes—as at present—a single head, and at one time (1895–97) a so-called bi-partizan board, divided nominally equally between democrats and republicans, was in power. Not even the extraordinary ability of Mr. Roosevelt, chairman of the board, could overcome the obstacle of divided responsibility. He left at least one good trace of his incumbency, the tenacity with which he held to the important doctrine that it was not the province of a commissioner to criticize the laws under which he acted, but to enforce them.

Since then has come the era of the "single head" to the department, a manifest improvement, since it is always better to have one (even a bad) "boss," than many—even many good ones. In fact the "bosses" of New York's police force have seldom been bad—that is, as executives never, it may be said, incapable; even the worst of them could have been wonderfully efficient if he had so chosen. With his views as to the ends to be attained this paper does not deal; to those views he was very loyal. Loyal too, after quite a different fashion, have been the army men who have been in control. But loyalty to an ideal is one thing, leadership in any sphere of activity when the foundation principles are radically defective, quite another. If for no other reason than the complexity and multiplicity of duties devolving upon the head of the department some of these must inevitably be slighted or neglected. The chief-of-police (whatever his title or under whatever code of laws he serves) ought to be free of virtually all routine duty.

But the really radical defect in the plan of organization of the department as applied to the commissioner, the flagrant, vital defect, at odds with all practical efficiency, real strength, and "the eternal fitness of things," is that in his hands are concentrated powers that under the conditions are incongruous, that he combines in his own person executive, legislative and judicial functions. The system in vogue in London, whereby the chief is an absolute autocrat, having power of dismissal without appeal, is better than this. But neither conforms to the requirements of equity; no man should be held—even voluntarily—as another man's vassal, and no American citizen should be deprived of his just right to the final judgment of the courts of his country. Again, as the law stands[1] the commissioner can be removed from office at any time and for any cause or no cause at the will, whim or caprice of either the mayor or the governor. Probably at some future time, if the laws remain as they are, this power of summary removal might not be undesirable; but certainly so insecure a tenure of office does not conduce to discipline. It renders the dignified office of commissioner something very like that of a lacquey, and that not to one master, but to two.

Comparison of the regular army with the police force shows most conclusively that for the latter there should be a legislative body, willing, to the same extent that congress is willing, to abstain from continual interferences, and to be guided largely by expert opinion derived from those who actually do the work and are familiar with practical conditions. Whether this body shall be similar to the old-time board of commissioners, whether the board of aldermen shall assume these duties, or a board constituted upon entirely new lines, these are matters demanding much thought and careful consideration. But, however this legislative body may be constituted, its function should combine those which

[1] Charter of the City of New York, Chapter VIII., Police Department.

for the army are now distributed between the war department, with its several bureaus, the general staff and the committees on military affairs of congress. In this way the chief officer of the police force would be called upon for no more than advisory assistance, being left free for the work of supervision and command. As a general in the field, he should have under him an adequate staff, responsible only to him and reporting only to him, and being clothed with powers as his representative. In time of riot or disorder the powers of the chief should be greatly increased; in effect his personal authority, while not extending of course to that of "life and death," should really for the time supersede the civil. To a military man there is something ludicrous in the idea of gentle dealings with a mob. It may be political heresy to say so, but no chief of police should discriminate between a band of murderous ruffians—if you choose avowed brigands—and those—hardly less ruffianly—who use and utilize the striking of honest workingmen for better conditions for purposes of pillage and violence. If a mob knew that the orders were—"Shoot to kill!" unlawful assemblages would quickly become unknown.

So far as *discipline* goes the police have seldom been other than disciplined. But to impose *military discipline* upon a policeman is not only impossible except when he becomes part of a battalion or when mobilized to resist and suppress disorder, but is usually quite undesirable. The duties of a patrolman on post are not in the least like those of a private soldier. He is an officer, must be treated as an officer, and his duty must be compared to that of an army officer. He is almost constantly beyond the oversight and control of a superior; he is bound to act by himself and obliged to think for himself. He is not an enlisted man, whose duty is largely that of blind and prompt obedience, but a citizen temporarily bearing arms for a specific and limited purpose.

The method of discovering and applying correct principles *applicable to all bodies of men acting under authority* to the police force; to do away with improper conditions; to reconcile discrepancies, and to establish the administration of the department upon a stable foundation, ought to be the work of a suitably constituted commission. This commission should be appointed by the governor, or preferably the mayor, under authority of an act of the legislature. This commission ought to be composed in part of graduates of West Point, in part of captains of police in sympathy with the work, the police commissioner, and one or two civilians, of whom one at least should be a lawyer thoroughly versed in municipal affairs. There is an old adage that, "A commission is a noun of multitude which may signify *many*, but seldom signifying *much;*" but we have equally good authority that, "In a multitude of counselors is safety."

If not already familiar with the history of the department, it would

be the manifest duty of the members of this commission to "read up" the entire subject, making themselves fully acquainted with the progressive steps by which the old-time watchman evolved into the municipal force, that having been displaced by the metropolitan police. They will find a continual rather than continuous progress towards better things in ways of organization, each commissioner having left something tending towards improvement; until, coming to the present time, a degree of practical efficiency is found probably nearly as great as under existing laws the force is capable of attaining.

But the present conditions can not be safely reckoned upon for continuance. The wide-spread and deplorable corruption that at times has disgraced the department may at any election return. The very efficiency, the very decency of the present administration may be the chief factor in bringing about a change far more likely to be for the worse than for the better. The spirit of that notorious and wonderfully able faction that for almost a full century has imposed its malign influence upon New York simply awaits a renewed opportunity. Not even four years of purest political and business methods can so dilute the foulness of the past as to make palatable the promise of the future. Do not mistake my meaning. The contest for good government in New York is not between democrats and republicans, nor is it between a faction of democracy and a coalition of opposed forces; nor is it surely between Tammany Hall and the so-called "better elements." It is in fact a phase of that interminable quarrel between the narrow "Puritan" and the broad "Cosmopolitan" ideas of civic administration; between a too tenuous ideality and practicality; that to legislate for the morals of the citizen, and to enact laws in their nature "sumptuary" will always fail of their high purpose. The limitations of enforcible authority ought to be recognized and never overstepped. The purpose of the police should be confined strictly to the preservation of the peace and the orderly and lawful maintenance of law and order. So long as human nature exists human infirmity will always evade human statutes. Smite vice if you will, but inevitably the harder it is smitten the wider will it be spattered, the more room will it find for contamination; it may be diffused; it can not be annihilated.

With overt crime the record of the department has not been entirely inglorious; but in dealing with the vicious propensities the results have been very far from successful. The reasons are notorious—the men "higher up," even perhaps the man highest up, for political ambition or the profit of the pocket, may have connived at or incited a system of paid-for immunity. At one time there has been extreme laxity, at another rigorous—and sometimes illegal—enforcement of arbitrary and unavailing laws. These concerning such iniquities as the saloons, the social evil and "gambling" in all its numerous forms have changed and

fluctuated, capriciously, at the behest or caprice of some "boss," or—what is almost equally deplorable—the urgency of sentimental opinion. It is all iniquitous, or worse, it is ridiculous. Whatever we may think of the "effete civilizations" of continental Europe, these matters have been settled there, not well, that may be admitted, but wisely and prudently, in accordance with human reason recognizing its inability to cope with human instinct.

Although Tammany Hall is readily recognized as "notorious," and has certainly the reputation of having been grossly corrupt, few, it may be said, are aware of the extraordinary strength of that organization or its mastery of the problems of civic science. That it has been almost exclusively a "one-man power" accounts for much of its ascendancy and effectiveness. Left alone, untrammeled by interference from without, it could be counted upon to give to New York city a truly efficient and metropolitan government. For its analogy we may look to the old Mormon hierarchy of Utah. There were found—previous to "gentile" interference—side by side with a custom revolting to humanity's purest sentiment and degrading to civilization, a condition of peace, prosperity and outward decorum almost idyllic. So long as the "latter-day-saint" had his way, he saw to it that the way was made pleasant for everybody. It has been much the same with Tammany during its periods of power; the arts of municipal dominion and those of loot and spoliation have gone hand in hand, and both have been reduced to scientific principles. During every so-called "reform administration" numerous hold-overs from a previous Tammany régime have been retained in office; and it is safe to say that a large percentage of efficiency of both the Strong and Low mayoralties was due to the experience of these men. In fact, if any especially difficult or delicate piece of work was required, it was almost invariably a Tammany "heeler" who was called upon to do it. It was not the high-toned moralist or well-meaning theorist in civics, but the man of practical knowledge. The Tammany man—whatever his faults—was always "on to his job."

This subject—the science and art of municipal government—will be, if not the first, not the least important that the commission will have to investigate. It can find no object-lesson more worthy of attentive study than that furnished by the despised and rejected Tammany. With far-seeing sagacity that institution seeks out and attaches to its service young men who give evidence of abilities—either brilliant or solid. Through the district leaders youths are constantly being taken up, sedulously trained, and given opportunities—some for hard work, and some—the exceptional ones—for real distinction. It is thus that the organization is in great measure recruited and the system perpetuated. Could anything be more masterly? Then do not let us smile at or ignore it; still less revile it; but rather emulate it as to method in

order to emasculate it as to purpose. Be sure its cohesion is too indurated to become friable by a few years of adversity. The "Tammany tiger," drowsy as he may seem, sleeps with one eye open, never relaxing vigilant watchfulness for the chance to pounce upon the city fang and claw.

In times now somewhat past appointments to positions on the force and promotions therein were managed usually by district leaders, "pull" being largely a substitute for merit, and there was (if common report may be trusted) a price-current for the goods.

The stream of insidious and blighting influence is not to be restrained or diverted by any ordinary counter force, or by any moral suasion; the remedy must be radical, human nature's quality of cohesive habit be overmastered by that stronger habit—also human-natural—of the potency of early training, and that moral health is more "catching" than moral disease. The strength of the power adverse to purity and legality in New York lies in the police force, and that can be purified only by purifying the sources of influence, by a new and totally variant method of selecting aspirants for the shield and baton. It will be necessary to establish a *school of instruction*—a police cadet academy.

Candidates for admission to this school should be chosen by an examination strictly competitive; the dictum of the political "boss" would be dispensed with, being replaced by the findings of fact as to qualification of the civil service. Some of these qualifications may be stated: book learning, beyond the merest rudiments of "the three r's," should not be exacted; moral character, physical stamina, including suitable height, weight and chest measurement, and "brightness," ought to be the controlling requirements. Strength and bodily endurance should be of a quality to enable the youth to stand the strain of his exacting calling, not only for a time, but all through life until age should disable him. The age limit for admission should be fixed comparatively early; from sixteen to twenty-one would approximate the desirable ages. As to residence, etc., citizenship or that of parents, for one year prior to admission, as well as residence in the state for one year, should be as now required. In estimating character I would suggest an entire overhauling of some of the customary ideas of theoretical reformers; "piety" ought neither to count nor discount; neither the timid (whose pluck can be toned up) nor the "bully" (whose audacity can be toned down) should be barred out. While a mean or contemptible action—and of course conviction of a felony—ought to exclude beyond hope an aspirant, let it not be forgotten that no material is more promising than that found in the pronounced honest "tough." To some this idea may come as a rude shock—that it is educational "heresy." To such, however, the entire change may be shocking.

A number of models exist for the sort of training school contem-

plated. First and most influential is the Military Academy at West Point. Our regular army is officered in three ways: by appointment of civilians based upon the results of proficiency as determined by an army board; second, from a list of enlisted men and non-commissioned officers found duly qualified; but now mainly (and certain in the near future to be entirely) from the promotion of graduated cadets.

Although West Point has long been in the focus of publicity, and has a certain and very great renown for thoroughness of instruction and the general high average of the material it turns out, few indeed are fully aware of the essential nature of that institution's merit. This consists, not so much in the value of the education—though this ranks with that acquired at the best technical schools—as in the nature and extent of the course of training, influence and discipline. Here young men for four years of the most impressionable time of life are set and held wholly apart from all civil influences of a kind to divert them from the mastery of their profession. The West Point method is exacting to a degree almost cruel in its rigor; so exacting that of any entering class not more than half succeed in being graduated. It teaches—and enforces pitilessly—thoroughness, exactness, responsibility. But more and deeper than this, seldom is felt, except for purposes of instruction, the hand of outward authority. The commandant and his assistants, the "tactical officers," are seldom in evidence; for almost all purposes of organization, drill and restraint within regulation limits, the method is self-acting, largely automatic; from the room and tent orderlies to the adjutant and captains, the corps of cadets governs itself.

And this government is not of force, as the idea of compulsion is ordinarily understood. The real governing power is that most potent of moral forces—public opinion. From first to last, in big things and in trivial things, a cadet in matters of duty is always "on honor"; he is bound to report not only others' derelictions, but at certain times and for certain purposes, his own. The severity of the prevalent code may be inferred from the following, taken from a New York daily of July 3 last:

> A member of the new class was brought before a court-martial on a charge of making false statements to the officer of the guard.
>
> "Are you chewing gum?" the officer asked. . . . "I am not," — is said to have replied, and an investigation showed that the answer was false.
>
> This is the first time in a great many years that a cadet has been dismissed from West Point for telling an untruth, and the authorities feel keenly the disgrace.

I imagine that many will find in this instance, not justice, but undue and disproportionate punishment for what they may regard as a trivial offence. To chew gum in ranks is indeed trivial; to lie about it (under the West Point system) simply unpardonable. The West Point man is not better, perhaps, morally than the average of his fellow citizens out of

uniform; but the penalty for departure from the right line of conduct is so terrible, so inflexible, as to fasten upon him—if not naturally straight—a mechanical equivalent for straightness that, become habit, tends to render him immune to temptation. Some graduates have gone fatally wrong; but the percentage of such is amazingly small.

Then there is the Naval Academy at Annapolis, whose methods are virtually identical with those of West Point. Both these institutions ought to be visited and much time spent in acquiring the proper point of view. The post-graduate schools of the army should also have some attention paid to them; but more influential will be found the schools for molding the man-in-the-ranks, one of which is at Fort Slocum on Davids Island, near New Rochelle. Still more interesting and instructive will be the training-schools for naval apprentices. Of these there are four, one at Newport, R. I., another at San Francisco, and still others at Norfolk, Va., and at Lake Bluff, near Chicago, while the school for the revenue cutter service, now located at Arundle Cove, Maryland, but to be removed to New London, Conn., will furnish material for study. The navy department has printed an instructive booklet: "The Training of a Man-O'Warsman," well worth attentive consideration.

When the methods of all these, as well as many private institutions, have been carefully examined, and their force and meaning in each particular case been thoroughly digested, then will come the difficult task of application, of deciding as to what shall be included and what avoided in a school for New York's ten thousand. As to the location of the school, undoubtedly it ought to be so situated as to be quite separate and apart from civilian pressure, at least from civilian contamination. At the same time no attempt should be made to effect isolation or undue exclusiveness; on the contrary, proper provision should be made for visitors, relatives of the police cadets and others, and these should be invited to rather than prohibited from acquiring full knowledge of the processes of the institution. The locality selected ought to be within convenient distance from the city, with the view of affording easy access and opportunity for the graduating class (such as is now given during the six months probationary period) of accompanying regular patrolmen on certain tours to gain a practical, first-hand knowledge of actual duty. As a site none could be more suitable than either Wards or Randalls Island, though it is not probable that either—so admirably fulfilling some of the city's greatest needs, by the Manhattan State Hospital on the former and the department of public charities in the latter—could be made available. If the rapid growth of the city were not likely to render Pelham Park unsuitable in the near future, that site could be made to serve the uses of the proposed academy. But this consideration can safely "await the event"; if once the founding of

such a school is decided upon and legalized, the rest is bound to follow.

In a paper necessarily so brief nothing more than suggestion can be offered as to the course of instruction. Undoubtedly this should attempt nothing in the way of higher education; but graduates should be thoroughly grounded in arithmetic, perhaps algebra, with a fairly good knowledge of the rudiments of physics. There should be a course in elementary law, and due attention should be paid to American history and geography. But all theoretical studies should be subordinate to the practical essentials. Minute, detailed and constant instruction in "rules and regulations" and in every phase of an officer's duty with practise in "Moot-Courts" ought to be accompanied so far as possible by actual service, especially that in the final year duly authorized service on post should be provided for. Every student would be trained for duty in case of fire and riot, and in the use of motor-cycles, bicycles, and the use and care of horses and equipment. Throughout the course constant daily instruction would be given in infantry drill and the use and care of small arms, and the duties of members of such special squads as the tenement house, the health and boiler squads must be made familiar to all graduates. Much attention would be paid to all forms of athletics and "first-aid" to the injured and ill would be a specialty.

In addition to the general plan of instruction applicable to all, it would be highly desirable to establish special courses, to be taken by those students who distinguish themselves by marked adaptability. While every man should be taught to ride, a few might be selected for extraordinary practise, with a view to positions as mounted men. Every one should have a good general knowledge of "administration," but a certain number might be further instructed in all branches of accounts, bookkeeping, etc. Other branches, such as the bureau of electrical service, could be made the subject of a special course. The theory of "detection of crime" by a competent expert might be taught to a certain number of students in the final year. This is not to cherish the hope of making skilled detectives, such being "born, not made."

The general scheme of the school should, I think, be so planned that from the first everything would tend to the eventual substitution of graduates for civilians as higher clerks, secretaries, etc. The corps of police ought ultimately to be made to contain within itself every element of service, including proceedings similar to courts-martial for trial of delinquents. Perhaps also in the end certain duties now performed by policemen could be more efficiently done by civilian employees. For instance, while a mounted man would always be held rigidly responsible for the health, grooming, etc., of his animal, civilian hostlers, cleaners, etc., might well be employed. In short, though special courses ought to afford room for special talent, and in time the rougher menial duties be relegated to outside hired assistants, every-

thing should be subordinated to the fitting of a youth to be a *police officer.* The course of instruction ought to be at least three years, and four would not be too long.

The initial steps in the founding of the *School of Police* would be by far the most difficult. The experiences at West Point are, however, available. Happy would it be for the city's ten thousand if a man could be found so well equipped as was General Sylvanus Thayer, who served for seventeen years as superintendent of the military academy and to whom its efficiency is almost wholly due. The conditions respecting the police school are in some respects even more onerous, especially that even now about 475 new men join the force annually, a number certain to increase rapidly with the growth of the city. One great advantage enjoyed by cadets is the intimate contact and influence of classes. This would be largely neutralized in the police school unless by a division into battalions, or some similar device, this could be obviated. In the beginning probably a better foundation could be laid for future efficiency by limiting the number of candidates for admission; this number to be increased gradually with each succeeding year.

A change so radical in the mode of admission to the ranks of the force may be safely reckoned upon to encounter adverse and censorious criticism. The very radicalism, subversive as it undoubtedly would be, of all the traditions of the past, would incite to opposition. The epithet "aristocratic," and that other phrase, a potent shibboleth to fanatical conservatism—"not close to the people," will find its opportunity. Political opposition, too, may be counted upon, certainly from the "machines," probably from even the free-lances. From the less thoughtful of the force itself may be anticipated, not so much opposition as ridicule and a certain good humored contempt. It is not difficult to imagine that in precinct station houses, members off post, particularly the younger, more flippant and "smarter," will be found indulging in considerable hilarity over the proposed innovation. But (as Victor Hugo says) "He who drains a marsh must expect to hear the frogs croak." Much, doubtless, could be done among the older and wiser officers to offset this feeling. Certainly at the outset the endeavor should be made to acquire their interest and sympathy and cordial assistance in establishing and promoting the new order. This may be found not as difficult as it now appears; at heart the vast majority of men greatly prefer clean ways to foul. Men grow trustworthy by being trusted.

Nevertheless, the first of the classes to be graduated, and the members of the school's senior class who would be taught by actual practise on post, must expect to encounter something not unlike "hazing." But we may be sure that graduates will be quite able to hold their own; they will have been taught how to do that. And they can console them-

selves for any slight contumely by the reflection that theirs is not an isolated case. Even to-day the young West Pointer on joining his regiment finds himself often sadly at a loss in many practical ways of the service, in which the old sergeants of twenty years or more standing are easily his superiors. So far as they dare and as army discipline permits they will "put up jobs" on these commissioned youngsters. When in the forties of the last century the naval academy was instituted at Annapolis, the old sea-dogs, ancient vikings who had worked their laborious way upward to a commission, had no few or gentle jibes for midshipmen and ensigns who, as it was said, "had crawled into the service through the cabin windows." All that sort of talk has long ago been ended; our navy is officered now by graduates, and the Deweys and Schleys and Sampsons and Evanses have proved themselves no unworthy successors of the Decaturs and Perrys, the Porters and Farraguts. So I am confident the young graduated police officer will have it in him to say: "Damn the torpedoes! Go ahead!"

It is not, I think, difficult to forecast the nature of the results that —though perhaps slowly—would modify and in the end entirely subvert those evils that have smirched and defiled New York. There would be abundant criticism; but it may be assumed that every good citizen and the powers of the daily press would stand for fair play. As class after class was added to the blue ranks it would not be long before the influence of the increasing numbei of graduates would begin to be felt. It would be seen and noted in rapidly decreasing number of charges, trials and dismissals, and in the lessening disproportion between arrests and convictions.

Doubtless objection will be made on account of the extra cost of the proposed school and the length of time that must elapse before any very marked benefit could be perceived; but surely if the principle is right a few years devoted to preparation ought not to prevent or postpone action. The prudent investor looks less to the pretty architecture of the home that he proposes to purchase than to the conditions unseen or underground—the drains and sanitary plumbing. The effects of education are in the end certain and salutary. Good habits acquired at the proposed institution in youth will form character not lightly to be flung away in manhood, the sort of character over which the smirch and stain of temptation shall inevitably lose its power. The roundsman's vocation should be dignified, his service compared with that of the army officer, for both are keepers of peace. To the officers of the regular army the Chepultepecs and El Caneys and Indian and Malay ambuscades come seldom, and when they come bring glory with them. But the policeman's duty is done in obscurity and the dark. For him there is but trifling applause and never any brevets. He is always on the firing line, always liable to lead a forlorn hope;

the revolver of burglar or anarchist is always imminent, the stiletto of some murderous swarthy ruffian or the bludgeon of one of the gas-house or car-barn gang.

What a splendid record is theirs! One needs only to read the story of those dreadful days of the mid-summer of 1863 to feel the blood tingle and thrill. The names of Kennedy and Acton, McCredie and Walling and Carpenter stand high on honor's roll. Then in July, 1871, under Superintendent Kelso, how gallantly those police detachments guarded the stout-hearted Orangemen down Eighth Avenue amid a howling mob. And when the throng, grown truculent, hurled missiles—though Irish Roman Catholics almost to a man—those brave fellows never stopped to reflect upon their sympathies, but fell upon the rabble, clubbing right and left. Happily the forty years have shorn the "seditious cries" of "Orange and Ribbonmen" of their venom. We "have done with a worn-out tale, the tale of an ancient wrong"; but I know of nothing in history's annals more heroic, more significant of devotion to duty; the incident deserves to be recorded with the exploits of Goliad and the Alamo.

From these and like constant and common perils has arisen in the police force a certain well-defined *esprit de corps* of bravery and devotion that goes far—very far indeed—to redeem the "graft," so long a menace and a shame, and the rank perjury that (largely from a mistaken sense of comradeship) has so often covered up offenses.

If, then, one common right impulse may so prevail that there is not a shirk or coward on the force, is it not highly probable that other high impulses may be made also to prevail—that to lie and to steal may become as impossible as to fear?

There will be those who will say that this is impracticable, too tenuous, too idealistic. Fortunately there is at hand an example of a similar result of early education, of influence and environment having stamped upon human nature in process of development an enduring effigy of honor's highest standard. At the outbreak of the war between the states, while with rarest exceptions every southern civilian, and virtually every student at a northern university, "went with his state" most of them to join the insurgent army, one hundred and sixty-two West Pointers, being graduates from the seceded states—full half of those in the regular army appointed from the south—withstanding the claim of home ties and the call of the blood, stood by the union and the flag. On this long roll of honor the most illustrious was George H. Thomas of Virginia—the "Rock of Chickamauga." It is not necessary to impugn the motives of those other gallant gentlemen whose ideas of "state rights" differed from ours that we salute and dip the colors to loyalty like this.

ASSORTATIVE MATING IN MAN

By Dr. J. Arthur Harris

CARNEGIE INSTITUTION OF WASHINGTON

I. Introductory

"The supreme misfortune is when theory outstrips performance," wrote Leonardo da Vinci.

He gave us, as far as I remember, no illustration of his epigram, but one is at hand in the modern attitude towards the Darwinian principles of natural and sexual selection. Exalted as they were on comparative evidence alone, and by post-Darwinian enthusiasts who were not only fertile, but liberal to a fault, in assumption, their debasement was inevitable. We are now in the period of reaction when men disparage selection, or dismiss it entirely as an evolutionary factor. Against this unreasonable extreme of opinion these essays[1] are directed. They are simple reviews, pretending merely to set forth honestly the results secured by biometricians in their studies of these exceedingly difficult biological problems.

Their purpose is, I admit, in reality two-fold. Not only are they a direct plea for a more open-minded—a stringently critical rather than a dogmatic—attitude towards the Darwinian factors, but an indirect appeal for a wider recognition of the biometric methods which make possible the measurement of the intensity of the primary factors of organic evolution.

The strongest arguments are those of quantitatively expressed facts. The best way of overcoming the prejudices and other obstacles against which the biometrician works is to allow these facts to speak for themselves, if possible in terms comprehensible to the layman.

Let us turn, therefore, to the available facts.

1. *The Problem of Intra-racial Sexual Selection*

There may be forces other than propinquity tending to fuse different races which through migration or otherwise come to occupy the same territory. Sociologists have, however, long emphasized intra-group marriages as one of the forces which tend to keep them distinct.[2]

[1] A first essay, "The Measurement of Natural Selection," has appeared in these pages, Popular Science Monthly, Vol. 78, pp. 521–538, 1911.

[2] For instance, Ripley ("Races of Europe," p. 49) says: "However strenuously the biologist may deny validity to the element of artificial selection among

This tendency to mate within the tribe is a factor of first-rate biological and sociological importance, serving as it does to maintain racial boundaries. But if sexual selection be a real factor in the evolution of races—in the differentiation of groups as well as in their maintenance—its action must be sought within the race, an intra-racial sexual selection must be demonstrated.

Sexual selection in man may, as Pearson long ago pointed out,[3] be of two kinds, preferential mating and assortative mating. By preferential mating one understands that certain classes of women are discriminated against by the average man, or by men as a class, or *vice versa.* By assortative mating one means that in the population of men and women who do marry, there is a definite tendency for certain classes of men to marry particular classes of women, and conversely.[4] An almost prophetic quotation from Pearson may render the distinction clear.

> For example, preferential mating might lead in a highly social community to the rejection of consumptive mates, while assortative mating might through localization or community of habit, lead to considerable consumptive correlation. Thus sexual selection as a whole may influence in diverse ways the inheritance of the consumptive taint.

Another illustration faces us in the problem of deaf mutism. Normal individuals discriminate against deaf mutes, for obvious reasons. There is a stringent segregation of the class, resulting from educational and social conditions, and as a result there is for the people, as a whole, a strong assortative mating, hearing people as a class marrying hearing, and deaf marrying deaf.

The scope of this review is limited to a discussion of the quantitative results which have been attained for assortative mating.[5]

It is needless to say that a subject so fascinating to man as any-

the lower animals, it certainly plays a large part in influencing sexual choice among primitive men and more subtly among us in civilization. Just as soon as a social group recognizes the possession of certain physical traits peculiar to itself—that is, as soon as it evolves what Giddings has aptly termed a 'consciousness of kind'—its constant endeavor thenceforth is to afford the fullest expression to that ideal.''

Westermarck (''History of Human Marriage,'' pp. 362–373, 1901) gives a terse summary of the social prejudices, tribal practises and laws concerning marriage between different castes, tribes or clans. Others are to be found in various sociological works.

[3] Pearson, K., *Phil. Trans. Roy. Soc. Lond.*, A, Vol. 187, pp. 257–258, 1897; also ''Grammar of Science,'' 2d ed., pp. 421–437, 1900.

[4] Thus in man sexual selection is a somewhat more complicated process than it has been assumed to be in the mass of writings on the lower animals.

[5] The quantitative data bearing directly on the problem of preferential mating are few. See K. Pearson, *Phil. Trans. Roy. Soc. Lond.*, A, Vol. 187, p. 258, 1897; ''Grammar of Science,'' 2d ed., pp. 425–428, 1900; *Biometrika,* Vol. 2, pp. 270–272, 1903.

thing pertaining to human mating has been the subject of wide speculation and assertion since the time of da Vinci.

Schopenhauer states that every person requires from the individual of the opposite sex a one-sidedness which is the opposite of his or her own. The most manly man will seek the most womanly woman, and conversely. Weak or little men have a decided inclination for strong or big women, and strong or big women for weak or little men. Blondes prefer dark persons or brunettes; snub-nosed, hook-nosed; persons with excessively thin long bodies and limbs those who are stumpy and short, and so on! Analogous superstitions are wide spread,[6] though differing in form. Westermarck,[7] in summarizing the views of various writers adds, "If contrasts instinctively seek each other, this may partly account for the readiness with which love awakens love."

Some have even ventured the opinion that where the husband and wife are unlike, the offspring are more numerous, or stronger! Again there is the popular superstition that after a long life together husband and wife come to resemble each other physically.[8]

Of course conclusions the opposite of all of these are not wanting.[9]

Such is the state of knowledge to which the unaided observation of a complex phenomenon can lead us—a snarl of contradictions. As far as we know, the only method of disentangling it and arriving at some certainty is the analysis of large bodies of observations by means of refined statistical methods.

[6] The way in which mere impressions may become stamped with authority by the approval of careless writers is illustrated by the following quotation, from a standard authority on sociology.

"It is almost proverbial that tall men choose short wives, and the union of tall women with short men is only a little less common. Thin men and plump girls fall in love, as do fat men and slender women. Blondes and brunettes rush irresistibly together."

[7] "History of Human Marriage," pp. 353–354, 1901.

[8] Fol ("La Resemblance éntre Epoux," *Rév. Scientifique,* Vol. 47, pp. 47–49, 1891) has tried to investigate this by means of photographs of newly married and aged couples, and while he concludes that there is a considerable resemblance between husband and wife, it is no more intense in aged than in newly-married couples.

[9] For example, Francis Galton, whose data and methods were not yet adequate for dealing with so complicated a problem, wrote ("Natural Inheritance," p. 85, 1894 ed.) with a caution which led him into error: "Whatever may be the sexual preferences for similarity, or for contrast, I find little indication in the average results obtained from a fairly large number of cases, of any single measurable personal peculiarity, whether it be stature, temper, eye-color, or artistic tastes, in influencing marriage selection to a notable degree. Nor is this extraordinary, for though people may fall in love for trifles, marriage is a serious act, usually determined by the concurrence of numerous motives. Therefore we could hardly expect either shortness or tallness, darkness or lightness in complexion, or any other single quality, to have in the long run a large separate influence."

2. *The Measurement of Assortative Mating*

The precise meaning of the term "assortative mating" may perhaps be made a little clearer in the process of explaining how the similarity or dissimilarity of husband and wife is measured.

Suppose a most highly refined socialistic community should set about to equalize as nearly as possible not only men's labor and their recompense, but the quality of their wives. It would never do to allow individuals to select their own partners—superior cunning might result in some having mates above the average desirability, which would be socially unfair!

The method adopted would be to write the names of an equal number of men and women officially condemned to matrimony on cards, and to place those for men in one lottery wheel and those for women in another. The drawing of a pair of cards, one from each wheel, would then replace the "present wasteful system" of "competitive" courtship. If the cards were thoroughly shuffled and the drawings perfectly at random, we should expect only chance resemblances between husband and wife for age, stature, eye and hair color, temper and so on; in the long run, a wife would resemble her husband no more than the husband of some other woman. In this case, the mathematician can give us a coefficient of resemblance, or of assortative mating, which we write as zero. The other extreme would be the state of affairs in which men of a certain type (that is to say men differing from the general average by a definite amount) always chose wives of a definite type; the resemblance would then be perfect and the correlation, as we call it, would be expressed by a coefficient of 1.

Fortunately, the meaning of correlation can be illustrated by a character for which the reader knows that there is a high degree of assortative mating. The table[10] shows the age of bride and groom in 2,500 Chicago couples. The swarm of figures showing the frequencies of different combinations spreads diagonally across the table, demonstrating that while men or women of any class marry consorts of varying ages, there is a pronounced tendency for individuals of the same relative age[11] to mate. From such a table the statistician calculates the equation to a straight line (or to a curve of a higher order) which describes approximately the change in the average age of brides associated with increase in the age of the grooms. The diagram (Fig. 1) shows that the agreement of the theoretical line with the empirical means is very close indeed.[12] Or he may express the closeness of correlation quite independently of the absolute values of the two characters on the scale of

[10] From a paper by F. E. Lutz, "Assortative Mating in Man," *Science*, N. S., Vol. 22, pp. 249–250, 1905.

[11] Since women marry younger than men, relative, not absolute, age must be specified.

[12] Such differences as occur are probably due to errors of random sampling.

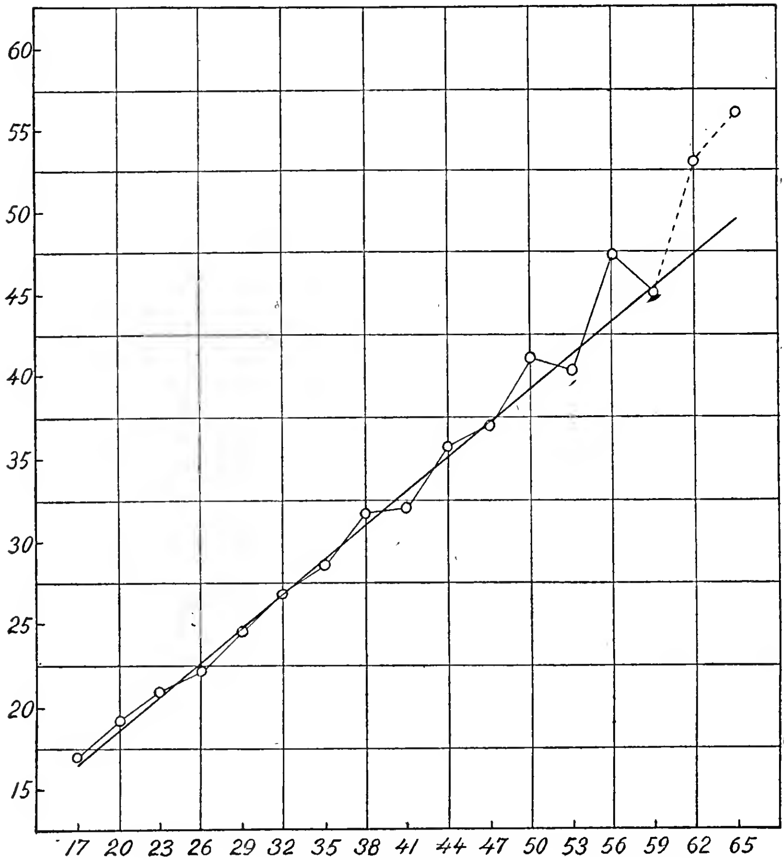


FIG. 1. AGE OF GROOM.

TABLE I

	13–15	16–18	19–21	22–24	25–27	28–30	31–33	34–36	37–39	40–42	43–45	46–48	49–51	52–54	55–57	58–60	
64–66	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
61–63	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
58–60	—	—	—	2	—	—	—	—	—	2	—	1	1	1	1	2	10
55–57	—	—	—	—	—	—	—	—	—	2	2	—	1	—	2	—	7
52–54	—	—	1	—	—	3	1	2	1	2	3	4	1	1	1	—	20
49–51	—	—	—	2	1	2	—	4	1	3	2	4	4	2	1	—	26
46–48	—	—	—	1	3	3	3	2	4	5	3	2	2	—	—	—	28
43–45	—	—	—	4	2	5	6	6	6	5	6	2	—	1	—	—	43
40–42	—	1	3	7	10	8	4	9	10	8	1	—	2	—	—	—	63
37–39	—	1	2	12	16	15	9	8	15	—	6	3	1	1	—	—	89
34–36	—	2	13	26	29	23	21	11	3	5	4	—	1	1	—	—	139
31–33	—	3	21	35	48	34	20	7	4	4	—	—	—	—	—	—	176
28–30	—	14	74	117	100	52	16	3	4	2	—	—	—	—	—	—	382
25–27	—	59	217	197	101	20	3	1	1	—	—	—	—	—	—	—	599
22–24	—	76	334	169	32	4	4	1	—	—	—	—	—	—	—	—	620
19–21	1	113	147	25	5	3	—	—	—	—	—	—	—	—	—	—	294
16–18	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
	1	271	812	597	347	172	87	54	49	38	27	16	13	8	6	2	2500

-1 to $+1$. In this case, the correlation is $+.75$, or about three fourths of the distance up the scale of 0 to 1, from no resemblance to perfect identity.[13]

To determine whether men and women tend to parity or disparity in matrimonial choice, we must, therefore, take a large number of mated pairs at random from the general population, sort them into groups according to some characteristic—quantitatively measurable whenever possible—and determine by means of the statistician's coefficient of correlation whether generally similar or dissimilar groups of men and women tend to mate, and how strong this tendency to parity or disparity is. Throughout this paper the intensity of assortative mating will be expressed by the coefficient of correlation. The reader will have to bear in mind merely that positive coefficients indicate a similarity and negative coefficients dissimilarity in husbands and wives as compared with random pairs of men and women from the population.

II. Assortative Mating for Physical Characters

1. *Stature*

The psychological basis of the popular notion that men and women seek disparity rather than parity in the stature of their mates is not far to seek. On the streets the linear wife and spherical husband, or the reverse combination, appeal to our sense of humor while the multitude of similarities pass unnoticed. Yet when lumped on the statistical scales the modal multitude may outweigh the extreme combinations whose incongruity provoke a smile as they pass to the front circle after the curtain has gone up.

With the rough statistical methods then available, Galton[14] was unable to detect any tendency towards marriage selection with respect to stature, but Pearson[15] on the same data as early as 1897 suspected homogamy. The results from his own more extensive family records are shown in Table II.[16] For convenience the figures for forearm and span are also given.

[13] This value is perhaps a little too high. However much popular opinion may overestimate women's reticence concerning their ages, statisticians know that even the correct age of marriage of both men and women is hard to obtain. Especial difficulty is to be expected near the extremes of the series. Those embarrassed by years may declare themselves of legal age, or even deduct a few years. Those who are not yet of legal age may falsify to obtain a license. As Lutz aptly remarks, these figures, "instead of telling the exact truth, show us the state of things modified somewhat by man's idea of how he thinks they had better be."

[14] Galton, F., "Natural Inheritance," p. 206.

[15] Pearson, K., *Phil. Trans. Roy. Soc. Lond.*, A, Vol. 187, p. 273, 1897; also, "Grammar of Science," 2d ed., pp. 429–431, 1900.

[16] Pearson, K., and A. Lee, "On the Laws of Inheritance in Man. I., Inheritance of Physical Characters," *Biometrika*, Vol. 2, pp. 372–377, 1903.

TABLE II

	Husband's Character	Wife's Character	Assortative Mating (Correlation and Probable Error)
Direct correlations	Stature	Stature	$+.2804 \pm .0189$
	Span	Span	$+.1989 \pm .0204$
	Forearm	Forearm	$+.1977 \pm .0205$
Cross correlations	Stature	Span	$+.1820 \pm .0201$
	Stature	Forearm	$+.1403 \pm .0204$
	Span	Stature	$+.2023 \pm .0199$
	Span	Forearm	$+.1533 \pm .0203$
	Forearm	Stature	$+.1784 \pm .0201$
	Forearm	Span	$+.1545 \pm .0203$

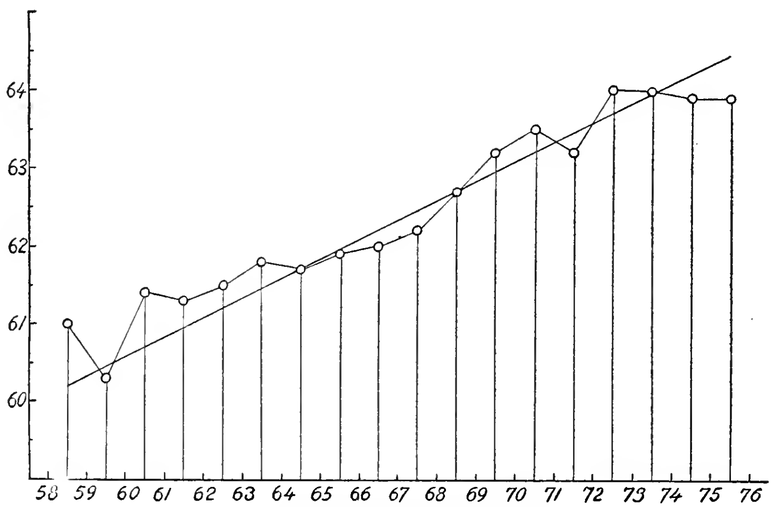


FIG. 2. SCALE OF HUSBAND'S STATURE.

We find a resemblance $r = +.280$.[17] Thus there is a very pronounced similarity in stature between husband and wife.[18] This is made clear by diagram 2, which shows the empirical and the (smoothed) mean statures of wives of husbands of different heights.

2. *Other Bodily Characters*

Data for physical characters other than stature are few;[19] the only

[17] From Mr. Galton's "Family Records," Pearson found the resemblance for man and wife to be $+.09 \pm .05$, but between fathers and mothers of adult children, as in the case of his own material, it was $+.18 \pm .02$. Considering the smallness of Mr. Galton's pioneer series, the results are not in bad agreement.

[18] Galton's series of data ("English Men of Science," pp. 22–24, 1895) for the parents of English scientific men is too small (embracing only 62 cases) to give conclusive results for assortative mating. It indicates, however, no tendency towards contrast.

[19] I have omitted Galton's ("English Men of Science," p. 21, 1895) data for the "figure" of 71 pairs of parents of English scientific men, since the

important ones are forearm and span in Pearson's investigation.[20] For the direct[21] comparisons the resemblance is quite material, amounting to about $+.200$. Cross correlations are in general somewhat lower. Possibly the assortative mating is primarily for stature, while the resemblance for forearm and span arise merely because these are closely associated with stature. This point is not as certain, however, and deserves more attention.

For forty-eight families of East European (Russian) Jews living in New York City, Boas[22] found an assortative mating for cephalic index (relative head breadth) of $r = +.15 \pm .10$.

Lutz's interesting data on the inheritance of the method of clasping the hands[23] show a positive sign in the correlation between the two parents, but it is so very small that no significance is to be attached to it.

3. *Complexion and Hair and Eye Color*

Complexion and hair and eye color are conspicuous with stature in the popular superstition of "the charm of disparity" in human matings.

The calculation of the intensity of relationship in the case of a character which like eye color is not quantitatively measurable presents considerable difficulties, and the results vary with the method employed. From an analysis of Francis Galton's "Family Records," Pearson[24] has deduced the following values:[25]

Correlation by four-fold method	$+.10 \pm .04$
Mean contingency	$+.31$
Mean square contingency	$+.26 \pm .03$

numbers are too few to calculate the contingencies on the basis of his grouping, and the classes are too indefinite for satisfactory combination.

[20] Length of forearm is the distance from the bony projection of the elbow, with the arm folded as much as possible, to the tip of the middle finger. The span is the greatest possible distance between the tips of the middle fingers of the outstretched hands.

[21] By direct correlation we mean the degrees of resemblance calculated for the same organs in husband and wife, by cross correlation those in which the characters are different. The entries in the table makes this quite clear.

[22] Boas, F., "Heredity in Head Form," *Amer. Anthrop.*, N. S., Vol. 5, p. 532, 1903.

[23] Lutz, F. E., *Amer. Nat.*, Vol. 42, pp. 195–196, 1908.

[24] Pearson, K., *Phil. Trans. Roy. Soc. Lond.*, A, Vol. 195, pp. 113, 149–150, 1900; "Grammar of Science," 2d ed., pp. 431–437, 1900; *Biometrika*, Vol. 5, pp. 475, 1907.

[25] Yule (*Journ. Anth. Inst.*, Vol. 36, p. 359, 1906) has drawn these results into question on the supposition that they may be due to a personal equation or bias of the observer, which might lead him to classify both members of a pair alike. His criticism is well answered by Pearson (*Biometrika*, Vol. 5, p. 475, 1907).

The only series of data for hair color in husband and wife (where one may not suspect artificial selection of cases) is that given by Mr. Galton[26] for the parents of English scientific men. I have grouped his data into three classes, and calculated the coefficient of mean square contingency, which is + .34. No stress is to be laid on the result, since the number of cases is small and the coarse grouping—which is necessary if the constant is to be calculated at all—unsatisfactory.

4. *Physical Defects and Pathological Conditions*

To Alexander Graham Bell[27] probably belongs the credit of first laying great stress upon the social consequences of assortative mating. The title of his memoir, "Upon the Formation of a Deaf Variety of the Human Race," sufficiently indicates the seriousness with which he regarded the intermarriage of the deaf.

Probably assortative mating for deafness is more nearly perfect than that for any other known character. The reasons for this are patent. Hearing individuals rarely choose non-hearing mates. When both partners are deaf, on the other hand, they are united by the strong bond of fellowship and sympathy growing out of their similar condition, they communicate with each other with perfect ease and freedom, and the social interests and sympathies outside their own home are the same.

The extensive records given by Fay[28] rather than those used by Bell in his pioneer study may furnish illustrations.

Table III. shows that in the marriages of the deaf, 72.5 per cent.

TABLE III

Marriages of the Deaf	Number	Percentage
Both partners deaf	3,242	72.512
One partner deaf; the other hearing	894	19.995
One partner deaf; the other unreported whether deaf or hearing.	335	7.493
Total	4,471	100.000

have both of the contracting parties deaf as contrasted with 20 per cent. in which one is deaf and the other a hearing person. When we consider that in the general population of the United States there are roundly 1,500 hearing persons to one deaf, and consequently about 1,500 hearing persons to one deaf from whom a given deaf individual might seek to select a life partner, we see to what enormous extent sexual selection is at work for this character.[29]

[26] Galton, F., "English Men of Science," p. 21, 1895.

[27] Bell, A. G., *Mem. Nat. Acad. Sci.*, Vol. 2, pp. 179–262, 1883.

[28] Fay, E. A., "Marriages of the Deaf in America," Washington (Volta Bureau), 1898.

[29] Schuster (*Biometrika*, Vol. 4, p. 473, 1906) was unable to calculate the precise intensity of the assortative mating coefficients for deafness because of the mathematical difficulties involved, but it is certainly considerably higher than + .90.

Bell laid great emphasis upon the influence of educational segregation, especially upon the use of a sign language, with its subjective influence on thought, in bringing about the intermarriage of the deaf. That this is a factor appears from Fay's elaborate records. He classified 7,277 deaf individuals according to the method of education and found that of those who attended boarding schools for the deaf, 86.2 per cent. married deaf mates, while of those who attended day schools, or both day and boarding schools, for the deaf 77.8 per cent. married deaf consorts.[30] In contrast are the records of those who attended no school for the deaf: in this class, 62.4 per cent. married deaf individuals. The difference between 62.4 per cent. and 86.2 per cent. probably indicates roughly the influence of scholastic segregation.

Fay also finds that of the pupils who attended exclusively oral schools 78.2 per cent. married deaf partners, while of those who were educated at schools not exclusively oral, or partly at schools exclusively oral and partly at schools not exclusively oral, somewhat over 86 per cent. of marriages were homogamous for deafness. Perhaps these figures indicate a sensible influence of the method of instruction.[31] Nevertheless, one cannot but be impressed with the intensity of the assortative mating that occurs independent of this factor. With no such isolation 62 per cent. of deaf individuals marry those who are deaf. Considering the intensity of the inheritance of deafness,[32] we see what grave social results may be expected from this tendency.

Apparently unions where both members are deaf are more happy than those where only one is so afflicted. Table IV. gives the best avail-

TABLE IV

Marriages of the Deaf	Number of Marriages	Divorces		Separations		Divorces and Separations	
		Number	Percentage	Number	Percentage	Number	Percentage
Both partners deaf	3,242	33	1.018	51	1.573	84	2.591
One partner deaf, the other hearing	894	25	2.796	33	3.691	58	6.488
One partner deaf, the other unreported	335	7	2.090	7	2.090	14	4.179
Total	4,471	65	1.454	91	2.035	156	3.489

able records indicating the "success" or "failure" of like and unlike matings. Of course divorce, separation or number of children do not tell the whole tale; they give rather a lower limit to the measure of domestic infelicity.

[30] In the cases where the mode of education is not known, 77.3 per cent. chose deaf partners.

[31] If the probable error of the percentages were calculated, their distinctness would appear much more open to question.

[32] See besides Fay's analysis of his data, a paper by Schuster, *Biometrika*, Vol. 4, pp. 465–482, 1906.

For general health in husband and wife, classifying as very robust, robust, normally healthy and delicate, Miss Elderton[33] calculated from Pearson's "Family Records" a relationship of + .27.

For freedom from constitutional diseases—*i. e.*, freedom from any specific pathological taint without regard to the strength or delicacy of constitution—Goring[34] found these resemblances for families of criminals:

Very poor and destitute	+ .17
Well to do and prosperous poor	+ .08
All	+ .11

The possibility of infection reinforcing constitutional likeness in consorts is presented by a disease like tuberculosis. From the evidence now available[35] there can be little doubt that if one member (husband or wife) of a pair be tuberculous the other is more likely to be affected than if the first be sound. In short, there is a correlation for tuberculosis between spouses which has sometimes been called "marital infection."

But such a term implies entirely too much. The correlations are not so high but that one may suspect them to be due, in considerable part, to assortative mating for the physical and psychical characteristics which underlie, or at least accompany, the predisposition to tuberculosis. Those who have analyzed the problem most minutely are inclined to attach importance to both factors, but to lay especial stress upon assortative mating.

5. *The Influence of Numerous Local Races*

The reader who is a keen traveler will probably suggest that the general population of England, whence most of the data have been drawn, is made up of local races differentiated with respect to physical characters,[36] and that marriages tend to be contracted between neighbors —*i. e.*, within the local race.

Pearson has emphasized the possibility of this factor[37] but with

[33] Elderton, Ethel M., "Stud. Nat. Det.," 3, London, 1908.

[34] Goring, C., "Stud. Nat. Det.," 5, London, 1909.

[35] The three chief papers are: Pope, E. G., "A Second Study of the Statistics of Pulmonary Tuberculosis: Marital Infection," edited and revised by K. Pearson; with an appendix on Assortative Mating by E. M. Elderton, Draper's Co. Res. Mem., "Stud. Nat. Det.," 3, London, Dulau & Co., 1908. Greenwood, M., "The Problem of Marital Infection in Pulmonary Tuberculosis," *Proc. Roy. Soc. Med., Epid. Sect.*, Vol. 2, pp. 257–268, 1909. Goring, C., "On the Inheritance of the Diathesis of Phthisis and Insanity: A Statistical Study based upon the Family History of 1,500 Criminals," Draper's Co. Res. Mem., "Stud. Nat. Det.," 5, London, Dulau & Co., 1909.

[36] That such differentiation exists is strikingly shown by anthropological maps, for instance those in Ripley's "Races of Europe," pp. 300–334, 1900.

[37] Pearson, K., *Proc. Roy. Soc. Lond.*, Vol. 66, pp. 28–32; also *Biometrika*, Vol. 2, pp. 274–275.

justice points out that his data for stature were taken largely from the professional classes—chiefly residents of London and other larger towns. While these marry in their own "sets," these can hardly be regarded as "local races." The records from cemeteries, to be discussed in the following section, were taken purposely from narrowly limited districts; tables were formed for each locality separately. Certainly such correlations can not be attributed to the heterogeneity arising from the mixing of differentiated samples. In other cases, the possible influence of local races has been well excluded.

Even if the demonstrated resemblances were due merely to the tendency to marry within the local race, and indicated no conscious or unconscious sexual selection on the part of individuals of the same race, they would nevertheless be of great interest as showing quantitatively the force of one of the factors tending to maintain racial boundaries.

III. Assortative Mating for Duration of Life

That human matings should so depend upon the visible physical and intangible, but none the less real, psychical characteristics as to give rise to a measurable bodily and mental similarity of spouses, while contrary to popular belief, seems not unreasonable. That this resemblance should extend to duration of life—a character quite unknowable at the time of marriage—appears at first thought highly improbable.

But duration of life is not a simple attribute. It is rather a conveniently measurable epitome of many physical and physiological traits, as well as of environmental conditions. Both its inheritance and the evidences which it furnishes of the action of natural selection in man probably depend upon its being the resultant of a complex of factors. May not assortative mating for appreciable personal characters result in an assortative mating for duration of life?

The answer given by the correlation between the age at death of husband and wife (Table V.) is affirmative—clear and emphatic.

TABLE V

Source of Material	Number of Pairs	Coefficient of Correlation Measuring
Wensleydale and district cemeteries..........	876	$+.2200 \pm .0244$
Oxfordshire cemeteries	890	$+.2500 \pm .0211$
Society of Friends' records....................	1,000	$+.1999 \pm .0212$
Mean..		.2233

Warren, Pearson, Lutz, Lee and others[38] drew their records from the tombstones of rural English churchyards and from the archives of the Society of Friends—two quite dissimilar sources. Yet the results are in remarkable agreement; considering the errors common to statistical constants based on numbers of a thousand or less, one can not assert

[38] "Assortative Mating in Man: A Cooperative Study," *Biometrika*, Vol. 2, pp. 481–498, 1903.

that they differ at all. The close agreement with stature, forearm, span and other physical characteristics is clear.

A criticism which may occur to the reader is that these resemblances are purely spurious, and due to the fact that husband and wife are not likely to be buried in the same ground unless they die within a short period of each other. This is precisely what would occur in districts with a shifting population. This very difficulty was anticipated. All urban churchyards were excluded because of the heterogeneous and transitory nature of the population. "In most rural districts, on the other hand, with a stable population, there is a very strong feeling—amounting in the case of the Yorkshire Dales almost to a superstition—that husband and wife must share the same grave." In view of the careful selection of localities and the agreement of results secured from Quaker archives with those from the gravestones, it seems clear that the resemblance can not be dismissed as purely spurious.

Duration of life is doubtless dependent upon environment as well as upon constitution. Slight differences in the healthfulness of the several parishes of a district might promote or oppose fullness of years in men and women alike. If this were true, the lumping together of the records from a number of churchyards would result in a correlation for duration of life, whether there be any real assortative mating or not. If this criticism be valid, random pairs of husbands and wives from the same parishes lumped together to form a table for the whole district, should show correlations as high as those for actual married pairs. The correlation really found was sensibly zero, demonstrating that local environmental conditions can not explain the results.

But within the same general environment, members of a family are exposed to a set of conditions peculiar to themselves. In a city block or country parish food, temperance, sanitation, risk of zymotic disease, and physical and mental habits differ greatly from family to family. In addition to the physical and social environment common to man and wife, there is also the fact that the death of one member of the pair has a profound effect on the other. Financial and associated domestic changes are often due directly to this cause, to say nothing of the overstrain of care during long illness or the shock of sudden death. May not the similarity in the duration of life of husband and wife be a consequence of domestic environment? This point was investigated by methods rather too complicated for explanation here, but which indicate that the sameness of home conditions can not account for the relationship.

Until further evidence is available, we must, therefore, conclude that there is a real, though assuredly unconscious and quite indirect, assortative mating for duration of life. Nor is this to be marvelled at, considering the results already noted for normal and especially for abnormal bodily characters.

IV. Assortative Mating for Psychical Characters

That psychical characteristics should play some part in human matings seems *a priori* highly probable.[39] Actual facts are, however, few.[40] Galton concluded[41] that even good and bad temper made very little difference in marriage selection, but he pointed out many difficulties of obtaining trustworthy evidence.

Elderton[42] found for "Intelligence, Temper, Temperament"[43] and success in career the values given in the accompanying table.[44]

Mental Character	Relationship
Intelligence	.33
Temper	.18
Temperament, excitable	.11
Sympathetic	.15
Reserved	.27
Success in career	.48

For insanity, working with Pearson's "Family Records" and using two different methods of classifying the "normal," "insane," "nervous" and "doubtful" entries so as to get the upper and lower limits for assortative mating, Miss Elderton[45] finds $+ .244$ as the lower and $+ .361$ as the upper limit, say roughly an intensity of $.30 \pm .05$.

[39] Theoretically, assortative mating should be absent in royalty where marriages are contracted by persons other than those most directly concerned, or are arranged in accordance with some political policy. Woods ("Mental and Moral Heredity in Royalty," pp. 272–273) thinks it can not be held to be entirely absent. He correlated the intellectual grades of 229 couples and found $r = + .08$, approximately, but with a probable error of $\pm .076$.

[40] I have given none of the coefficient for psychical characters calculated by Schuster and Elderton (*Biometrika,* Vol. 5, pp. 460–469, 1907) from data collected by Heymans and Wiersma. These give results which vary widely among themselves and if one takes those which seem the most likely to be trustworthily determined, he opens himself to the criticism of the selection of evidence. Personally, I have grave doubts concerning the value of data on psychical characters collected by the widespread circulation of schedules. The estimates are too much subject to personal equation and family bias. When they are entrusted to especially trained observers who work comparatively, the case is better.

[41] Galton, F., "Good and Bad Temper in English Families," *Fortnightly Rev.,* July, 1887. Reprinted in "Natural Inheritance."

[42] Elderton, Ethel M., Draper's Co. Res. Mem., "Stud. Nat. Det.," 3, pp. 30–35, 1908.

[43] Galton ("English Men of Science," p. 20, 1895) had only 22 cases where the temperamental characteristics of the parents were marked. He considers that there is a tendency for harmonious matings with respect to temperament.

[44] The signs, sometimes difficult to determine in the case of non-measurable characters, seem to be positive throughout, but in some cases there may be distinct cross currents, one tending to produce like and the other to give dissimilar unions. The intensity of resemblance for "success in career" is about double that for other characters, and is possibly to a large extent spurious, because subjective. The "success in career" of a wife is probably largely dependent on or judged by the opportunities which her husband's success gives her for displaying her own abilities.

[45] Elderton, Ethel M., *loc. cit.,* p. 35.

Goring[46] considers that assortative mating is a factor of greater importance in the upper than in the lower social classes. In his records for insanity in criminals, he finds an assortative mating + .35 for the "well-to-do and prosperous poor" while it is probably absent in the "very poor and destitute." [47]

V. Preferential Mating and Assortative Mating for Social Attributes

To mark off sharply social attributes from those which are physical and psychical is as impossible as it is idle. Certain traits dependent on wealth, family history, education or opportunity may be, for convenience merely, designated as social. To what extent do they influence mating?

Their potency is greatest in caste, royalty and peerage. Even in countries which pride themselves on the absence of social strata, wealth, family pride and feuds, religion and education, play their part in limiting the range of choice in marriage selection. But nowhere is mating within the class universal. The much-multiplied American dollar plays havoc with continental pedigrees. The pure breeding of the English nobility is a pretence; "the lawyer, the farmer, the silk-mercer lies *perdu* under the coronet, and winks to the antiquary to say nothing." Some day the weight of these social forces will be determined, but the proper kinds of facts are not yet available.

Alcoholism is one of those interesting cases in which direct personal or social influence may supplement and reinforce the resemblance possibly due to assortative mating. Goring,[48] dividing his material for English criminals[49] into three classes for social status, finds these coefficients of resemblance:

Very poor and destitute	+ .44
Prosperous poor	+ .58
Well-to-do	+ .69
All	+ .70

[47] As a check, Goring determined the correlation between phthisis in one and insanity in the other member of a wedded pair. The resemblance was found to be sensibly zero.

[48] Goring, Chas., "Stud. Nat. Det.," 5, p. 27.

[49] The reader in noting the high values given for alcoholism by Goring will remember that the individuals studied are the parents of criminals, and that there is a known association between criminality and alcoholism. From data collected by Heymans and Wiersma, Schuster and Elderton (*Biometrika*, Vol. 5, p. 468, 1908) calculated a correlation for tendency towards drink of + .24 to + .36. But there are several reasons for doubting the trustworthiness of these data.

[46] Goring, C., "On the Inheritance of the Diathesis of Phthisis and Insanity: A Statistical Study based upon the Family History of 1,500 Criminals," Drapers Co. Res. Mem., "Stud. Nat. Det.," 5, London, 1909, Dulau & Co.

For criminality, Goring's results will strike many as surprisingly low. They are:

Very poor and destitute	+ .18
Well-to-do and prosperous poor	not calculated
All	+ .20

An interesting point of an entirely different nature has been raised by Heron[50] who in a study of the distribution of sex in human families finds, "that in the free mating of man, families with a preponderance of female or male elements are not drawn upon equally with families in which the sexes are more equally balanced."

VI. Homogamy and Fertility

From the notion that in marriage "opposite poles attract" the step to the conclusion that dissimilar are more fertile than similar unions is so easy that it has sometimes been taken, though without any valid evidence in justification.

Fay[51] considers that marriages of the deaf are possibly slightly less fertile than those of hearing persons. When both partners are deaf the percentage of sterile marriages seems higher and the mean number of children in fertile mariages lower than in unions in which one member of the pair is a hearing person.[52]

Homogamy for stature[53] and for eye color[54] have been considered in relation to fertility.

But as yet the data are far too meager for such complex problems. The whole problem of the relationship between homogamy[55] and fertility is open to investigation.

VII. Significance of the Results

The statistical facts reviewed in this essay make it highly probable that a great variety of physical and mental characters influence human

[50] Heron, D., "On the Inheritance of the Sex-ratio," *Biometrika*, Vol. 5, pp. 79–85, 1907.

[51] Fay, E. A., "Marriages of the Deaf in America," pp. 16–18, 29–30.

[52] Age at marriage, economic status and other factors probably complicate the problem.

[53] Pearson, K., "On the Correlation of Fertility with Homogamy," *Proc. Roy. Soc. Lond.*, Vol. 66, pp. 28–32; also *Biometrika*, Vol. 2, pp. 373–376.

[54] Pearson (*Phil. Trans. Roy. Soc.*, A, Vol. 195, pp. 148–150, 1900; *Proc. Roy. Soc. Lond.*, Vol. 66, p. 323, footnote) has considered Galton's data without arriving at final conclusions. De Candolle (*fide* Westermarck, "History of Human Marriage," p. 335) states that the number of children is considerably smaller when the parents have the same color of eye than when they were contrasted. Wittrock (*Ymer*, Vol. 5, pp. vii–ix, 1885) was unable, on Swedish materials, to detect any difference in fertility between the two classes of marriages.

[55] Homogamy means merely the mating of physically or psychically similar individuals. Sameness of stock, endogamy, is of course not implied.

matings, and in such a way that, on the average, similar individuals tend to marry.

These results will probably be received with much scepticism. The "charm of disparity," the "selection of opposites," has been so long asserted that the notion will not readily be given up. Concretions of vague impressions compacted into popular superstition are not soon broken up by the hammer of logical deduction from scientific measurement. This scepticism of preconception can, however, be ignored; in time it must give way to orderly arranged facts. Yet the scientist should not forget that when cracked open, the nodules of popular belief are often found to contain a scrap of truth—and in his turn should avoid dogmatism.

Purely biological phenomena are far more complex than the majority of naturalists have realized. When social factors are superimposed the difficulties of research become almost unsurmountable. Pearson has warned us that "in many factors there may actually be two opposed currents, one giving a tendency for like to mate with like and the other marked by the fascination of extremes." Goring's studies of criminals vindicate one's *a priori* conviction that assortative mating may be influenced by social conditions. Human society differs so profoundly from place to place and time to time that, however great the temptation to generalization may be, it would be folly to press the conclusions far beyond the data which they represent.

Moreover, if the biometric results reviewed in the preceding pages must be fitted post haste into some evolutionary scheme, or find an immediate practical social application, each reader must be responsible for his own. The difficulties of interpretation are even greater than the dangers of generalization. To-day, an unfortunately insistent demand that every datum must count for or against some current theory has largely replaced the Darwinian spirit of collecting facts in the hope that when sound and sufficiently numerous, reasonable theories may be fitted to them. To-day "a fact is not a fact until it fits a theory." Personally, I feel as thoroughly satisfied that the time is not yet ripe for interpretation as I am completely convinced that in the differentiation and painstaking measurement of the intensity of the individual possible factors we have begun to move in the right direction in the attack upon the phalanx of problems which we designate as organic evolution. The immense value of these pioneer studies by Pearson and his associates lies in the fact that they represent the definite and substantial beginning of quantitative research which is so large a part of the solution of a problem.

THE PRICE FALLACY OF HIGH COSTS

By RALPH H. HESS, Ph.D.
University of Wisconsin

THE synonymous use of the terms *price* and *cost,* in their relation to the acquisition of things which may constitute a living, is responsible for a large factor of error in popular discussion and opinion concerning the so-called "high cost of living." Because statisticians have discerned a rise of approximately forty per cent. in the average of commodity prices within the decade, it is being taken for granted that the cost of living has advanced coextensively; and this conclusion has, in turn, become the premise of serious projects in contemplation of social and economic reform.

Although *price* and *cost* may, in conventional phrasing, be interchangeable without confusion of ideas, the discussion of changing commodity prices and concurrent costs of living necessitates a discriminating use of the terms. As a matter of fact, an increase in the average of prices may be no proof of change in the average cost of living during the same period; and, in any case, price changes offer only indirect evidence and unreliable criteria of cost factors and movements.

The *price* of an article merely indicates its money-value—its market equivalent in terms of the standard metal. The *cost* of an article, however, is the measure of conscious effort and sacrifice necessary to gain its possession—the exertion of labor, the discomfort of abstinence, and the forfeiture of time and resources essential to its production or acquisition. Prices are paid out of *income;* but income is conditioned only indirectly upon the backache and brain-fag of labor, and the time-consuming and capital-wearing processes of industry—these latter constitute *real costs.* Since both income[1] and prices are commonly expressed in terms of the dollar, it is necessary to consider the possible correlation of the two in any instance if one would arrive at an accurate understanding of the costs of living. Likewise, price-changes, during any period, must be measured against income-changes for the same period before a conclusion may be justified regarding changing costs of living. The problem is to trace the successive relations of economic effort to consequent income, of income to prices, and of prices paid to the subsequent utilities which constitute a living.

If the industrial, commercial and leisure classes of the population are collectively considered, total income and aggregate prices are subject to similar concurrent changes. It is a truism, often overlooked, that the sum of prices paid constitutes the total of wages, interest, rents and

[1] "Income" is here used in the sense of periodically accruing purchasing-power.

profits which compose the money-income of society and, *per se,* the direct means of acquiring the necessities and comforts of life. The measuring and estimating of changes in the cost of living, therefore, is resolved into a comparative study of incomes and expenditures. If incomes, expressed in terms of money, are found to increase more rapidly than contemporary expenditures or to decrease less rapidly, costs of living may be said to be declining; if converse relations exist, virtual costs are advancing.

It is doubtful whether a careful comparison of aggregate income and expenditure in the United States, during the régime of advancing prices following the depression of 1897, would show any considerable differential in their relative changes or any remarkable increment in the *average cost of living.* But it is quite possible that *aggregates* and *averages* may remain unchanged while a radical readjustment of incomes and costs is effected among individuals or among the differently circumstanced groups which compose the social organism. Indeed, it is quite plain that a readjustment of respective shares in the distribution of the total income among the different classes of the population is the *raison d'être* of present economic discontent, and a careful analysis of the apportionment of the "national dividend" affords a key to the current problems of living costs. If an increased proportion of the social income finds its way into the pockets of fortunate individuals and favored classes of society, other persons and groups must suffer a relative decrease in purchasing power. Since all buy in the same market, a part of the population possesses an increased proportion of cash to the prices which must be paid, and the exchequers of the less fortunate are inversely affected. In other words, persons identified with one economic class may experience an actual decrease in their cost of living, despite rising prices, while others must carry an increased burden, and, possibly, a third group may be affected not at all.

Space forbids an analytic treatment of the factors which have contributed to the unusual price movement of the last twelve years; they include such industrial and social phenomena as have affected the relative supply of and demand for the standard metal, on the one hand, and the supply of and demand for the things which make up a living on the other. That the unprecedented increase of the gold supply is a potent factor can not be denied; that there are other factors of equivalent significance is quite certain. Among the latter, are such socio-economic tendencies as effect a relative or per capita decline in the annual supply of the necessities and comforts of life and a consequent increased social cost of production, as well as an advanced scale of prices.

The following may be properly enumerated as characteristic attributes of social and industrial evolution which may contribute to changing costs:

First. Over-intensity of industry, nationally considered, thus passing the "summit" of maximum per capita productivity.

Second. Aspiration to ultra-standards of living, thus stimulating consumption regardless of productive efficiency.

Third. Centralization of industrial and commercial control resulting in suppressed output and monopoly-price.

Fourth. The accumulation of private fortunes and the consequent appearance of a leisure class and its concomitant of unsocial labor, capital and natural resources.

Among the above causes of changing values, there are certain items which exert a noteworthy influence in the readjustment of fundamental costs and incomes which is vastly more important than any question of prices. There are statistical data of unquestioned reliability which clearly demonstrate the course, although they do not afford an exact measure of the extent, of important kaleidoscopic changes in the distribution of income and the coextensive shifting of economic benefits among different classes of the population. It is this arbitrary shifting of cost-burdens, coincident with recent price fluctuations, that accounts for the prevailing outcry against advancing costs of living. Naturally, individuals and groups who fare badly in the process of pecuniary readjustment are prone to complain, and those who account an accelerating balance of income over costs are sanguine.

Whether the United States has reached or passed the industrial condition of maximum per capita productivity is a mooted question; some who have given much study to the problem of production are inclined to support an affirmative conclusion. That the multiplication of population and the exhaustion of natural resources have carried certain nations of Europe and Asia beyond the summit of production is well known. The Malthusian principle is inexorable, and when population threatens to overrun the natural springs of subsistence, the normal resultant is a scale of high prices and the exaction of excessive industrial costs in exchange for the means of living. Whatever may be the present relation of population to productivity in the United States, the cosmopolitan nature of modern trade and the fact that other countries have amassed populations in excess of their means to provide an average of comfortable living, have potential significance in problems of costs and subsistence. The further observation that the migration spillway of Europe conveys the surplus increment of prolific and improvident races to the United States at a rate of half a million a year, to be nurtured by "high-tariff wages" and the "fruits of abundant resources," suggests a factor of no mean proportions among the determinants of costs of living in America.

Advancing standards of living are properly considered as indicative of social progress; but economic limitations of social evolution are

omnipresent, and there is good reason to believe that current price movements portend an imminent check to the development and satisfaction of extravagant social desires. Collectively and individually, we are living better than ever before. We are working shorter hours, occupying better homes and cleaner cities, wearing better clothing, eating better food and being better educated—not only is this true of the wealthy and well-to-do, but of the poor and the indigent as well. But this rational form of "consuming-power" should not be confused with improvidence, or what has been associated in some minds with the alleged engulfing "cost of high living." Rational standards of living are justified by coextensive industrial efficiency. Progressive well-being tends to affect consumption and production in direct proportion; indeed, the stimulus to increased production normally exceeds the desire to spend, and no lasting influence towards advancing prices or costs results. If, however, expenditures are permitted to infringe upon the capital of the country, or of any particular group of the population, or even upon the rate of accumulation of savings, the effect on prices and costs will be immediate.

The centralization of industrial control, resulting in "wide-scale" enterprise and exclusive "occupation of the field," tends to eliminate output and advance costs. It makes little difference whether the differential advantage of centralization is of the nature of special privilege or superior efficiency of organization. In either case, industrial rivalry is forced from the field and, in the absence of official restraint, the exaction of monopoly charges is inevitable. The consequent shifting of the incidence of industrial returns may be ascertained by enumerating the respective beneficiaries and exploitees of the profit-taking process—the trade advantages of the one class measure the economic disability of the other class; and the attenuation of the incomes of the less favored, as a means to augment the profits of the more favored, is a significant attribute of changing social costs.

By the grace of strategic advantages of occupation and centralization, persons deriving incomes through proprietorship in relatively highly organized and capitalized industry are the recipients of differential gains which tend always to transcend price increments. Such persons are secure in the realization of a progressive ratio of purchasing power to prices. The so-called industrial and transportation trusts, the banking rings and investment pools, the labor unions and cooperative societies, and the associations of commission men and retail merchants are simply concerned in seeking to acquire the advantages of exclusion and organization. In each instance, united action for the elimination of waste and competition is the initial motive. "Cooperative efficiency in production" is the shibboleth of industrial organization; but one seldom fails to observe the tendency to a gradual metamorphosis of suc-

cessful "cooperation" into monopoly, and the simultaneous exchange of the ideal of *efficiency in production* for the slogan of *ability in acquisition*.

Economically considered, America has, until recently, been thoroughly democratic; that is to say, despite tendencies to social class and caste, the population has shared without essential discrimination in industry and production. But in late years possessors of the great fortunes which have been in the building for a half-century have begun seriously to devote themselves to leisure. In so doing, they have not only subtracted their own energies from the productive forces of the country, but they have increased their sumptuary demands and have alienated a host of laborers and a vast capital from the production of the necessities and comforts of plain living in order that a few may indulge an epicurean taste for the costly objects of vain and selfish desire. This tendency to luxury is leading students of market and industrial conditions to characterize the high bidding of wealthy and profligate spenders and of their improvident imitators as a significant cause of high prices; but a deeper analysis reveals the more vital phenomenon of *intensified social costs* attendant upon a relative reduction of the effective labor power of society and the subversion of a considerable part of the nation's capital. In this very dynamic aspect of modern life, one observes a tremendous increase in demand for the costly and enervating indulgencies of conspicuous expenditure and a more than proportionate decrease in the productive powers which contribute to the synchronous supply of the staples of life. Here, indeed, resides a fundamental problem in *national cost accounting*. The passing of the millionaire captains of exploitation and industry is imminent, and there is no more disconcerting contingency in the nation's future than the probable succession of a less hardy and energetic generation to their proprietary trusteeship of the country's wealth.

Price changes, which may be traced to an increased gold supply and the consequent depreciation of the dollar, react upon the cost of living only as certain reciprocal advantages and disadvantages are shifted among persons whose money incomes rest upon actual or implied contractural relations extending over the period of price change. For this reason, advancing prices are peculiarly advantageous to the debtor class, composed mainly of bonded business corporations, virtually discounting their obligations at an annual rate commensurate with the increase in prices. It is likewise obvious that expected returns to creditors and investors on securities bearing *fixed rates* of income are proportionately reduced. Wage earners and salaried persons are subject to a like disadvantage. Wage and salary scales are not readily readjusted and, especially, in their upward movements, show a considerable "lag" behind prices. Because of the prevalence of a customary

charge for many forms of professional service, such professions as medicine, dentistry and law may fail to command an increase in income sufficient to keep pace with advancing prices.

To avoid the popular error of attributing an increased cost of living to all persons under a régime of rising prices, and to reveal the actual effect of prices on costs, it is necessary to determine whether the majority of the population is included among those whose incomes have failed to respond to advanced charges or among the beneficiaries of high prices.

In the less fortunate class, which undoubtedly carries an increased burden of living costs, may be enumerated the following: (1) investors in fixed-income securities such as mortgages, bonds and life insurance; (2) unorganized wage earners; (3) salaried persons; (4) members of most professions; (5) proprietors of small-scale industrial and commercial enterprises; (6) middle-men and tradesmen not sufficiently organized to advance and maintain their charges coextensively with price movements.

In the more fortunate class, whose incomes bear a progressive ratio to prices and whose cost changes are, therefore, inversely proportional to price movements, we may expect to find: (1) proprietors of mortgaged and bond-issuing commercial and industrial enterprises; (2) proprietors of highly capitalized and centralized industries not subject to public control; (3) employers of unorganized labor and salaried persons; (4) members of highly organized trades and occupations; (5) grantees of public-service privileges whose net earnings support an advance in "franchise values" during the period; (6) proprietors of natural resources and recipients of tariff protection so circumstanced as to advance prices at will through a monopolistic control of supply.

There is an intermediate zone of economic condition which is practically free from the characteristic attributes described above. This neutral condition may be attributed to those whose incomes and expenditures are alike correlated with current prices, and is doubtless realized by a much larger proportion of the population than may at first appear. Many persons are so identified in their business interests with both characteristic groups as to realize no net change as a result of the advantage of either. Moreover, in so far as business is subject to competitive self-regulation and to reasonable official regulation, there may be a wearing away of economic inequalities of changing prices and a constant recruiting to the normal average of welfare.

The chief consideration involved in the question of prices and the cost of living is not the numerical measure of price changes nor the aggregate number of persons affected thereby; but rather the changing incidence of the burdens of life upon individuals and classes, and the logical results of disturbed economic stress upon the social structure.

A BUGBEAR OF REFORMERS

By Professor T. N. CARVER
HARVARD UNIVERSITY

TO the commonly accepted belief that water tends to flow down hill, a certain type of visionary would object that though such a statement might be true as an abstract principle, dissociated from the real world of human achievement, yet it is not true as a matter of actual economic fact because men have invented pumps and pipes which make water flow up hill. His position would then be precisely like that of Professor Miller in his recent attack upon the law of diminishing returns.[1] His argument is, briefly, that improvements in productive processes, combined with increasing accumulations of capital, may and do enable us to get larger products than formerly, in spite of what is generally called the law of diminishing returns. If our supposed visonary were asked why pumps and pipes were necessary, he could only answer: because water tends to flow down hill. Similarly, if Professor Miller were asked why inventions and improvements in production were necessary in order to enable increasing populations to maintain their standard of living, his only reply, did he not dodge the question, would be: because of the law of diminishing returns.

Professor Miller further suggests that the law of diminishing returns "closes the door of hope" because "hopelessness is inherent in a world of diminishing returns." Now the law of diminishing returns closes the door of hope only in the sense that gravitation closes it, and hopelessness is no more inherent in a world of diminishing returns than it is in a world of gravitation. Gravitation has closed the door of hope to many a visionary inventor who could not get his device to work because of the stubbornness of this law, but it has not closed the door to those who took it into account and adjusted their plans to it. Gravitation doubtless closed the door of hope to Darius Green, but not to the Wright brothers. Similarly, the law of diminishing returns, and its companion, the law of population, most effectually close the door of hope to the Darius Greens of economic reform, but not to those reformers who take these laws into account and plan in conformity with them.

Even though, as Professor Miller remarks, capital may take the place of land in a growing population, he overlooks one rather important fact, namely, that this substitution of capital for land on a large scale is the accompaniment of a change from agriculture to manufacturing and

[1] See THE POPULAR SCIENCE MONTHLY, for December, 1911.

commerce, and that it applies only within certain limited territories and does not materially affect the problem if we consider the world at large. Because several million people happen to make a living on Manhattan Island by substituting capital for land, it does not follow that the whole world could do the same, nor would it follow even if two hundred million people could make a living in a similar way within the present boundaries of the United States. Our country would not then be truly self-supporting, in any large and complete sense, any more than the Island of Manhattan, or the Island of Great Britain, or Belgium now is. All urbanized populations bring in the products of the soil from regions where soil is abundant, work them over in industries which require much labor and little land, and send them out again to exchange for raw materials, living all the while on the profits of this class of transactions. As these urbanized populations grow, it is necessary to send farther and farther, to wider and wider fields for the products of the soil. Why is this necessary? Why should not England get all her agricultural products from her own area? Merely because of the law of diminishing returns. To double the produce of the English farms would not double, but treble or quadruple, the cost of cultivation. That is what the law of diminishing returns means, and it never meant anything else. Because of this law England finds it cheaper to send to distant countries for her wheat and beef, paying the cost of transportation, than to cultivate her own farms with a sufficiently high degree of intensity to enable her to live off her own soil.

To be sure, the available waste land of the world is not all in use yet, and our increasing urban populations will be able, for many years to come, to thrust their transportation systems out farther and farther in order to secure these products which require land—space—superficial area for their efficient production. Therefore we need not worry about the food supply for a long time to come. It may, however, surprise some of our urban economists to learn how little modern science has enabled us to economize land, our inventions and machines having in the main, increased the product per unit of labor rather than the product per unit of land. So little has it increased the latter that, taking into account the rise in the standard of living, it is probable that it takes as much land to support the average family in any part of the civilized world to-day as it did when Malthus wrote his epoch-making work on population. By support I mean support in a complete economic sense. I mean that it probably takes as much land to supply all the things actually consumed by the average family to-day as it did then.

We could, to be sure, if we chose to do so, consume more of those crops which respond to intensive culture, such as corn, potatoes, bananas, etc., and less of those which yield their best results under ex-

tensive culture, such as wheat, beef, etc. This would mean a change in the standard of living. Possibly it might be a good thing to make this change in our habits; but why should it be necessary? Simply because of the law of diminishing returns. That is to say, in order that increasing populations may have plentiful supplies of bread and beef *from the same areas,* these crops would have to be cultivated more and more intensively. These crops do not respond readily to this method, and the cost per unit rises very rapidly, which, again, is due to the law of diminishing returns. Other crops respond somewhat better, but they also come under the same law, and eventually the point would be reached when more land would be better than less land, even for the growing of these crops. Wherever that is true, the point of diminishing returns has been reached. Wherever agricultural populations tend to spread as they are doing out west to-day, rather than to concentrate, it is a sign either of general insanity on their part, or of diminishing returns from land. I am one of those who believe that it is a sign of diminishing returns, that is, that these increasing populations find it more advantageous to spread over more land than to concentrate on the land already in their possession and try to get their living from those limited areas. That, again, means diminishing returns. Increasing the number of men working on a given area of agricultural land will not proportionally increase the products. That means a smaller product per man, though it may mean a larger product per acre.

The law of diminishing returns as ordinarily stated is, really, nothing more than a technically specialized statement of the fact that land is a limiting factor in production. A limiting factor is merely a factor upon whose quantity depends, in some degree, the quantity of the product. Wherever it is true that more land is better than less land, or where one can say, "more land more product, less land less product," there land is a limiting factor and the law of diminishing returns is in operation. From a narrow and piecemeal view, it sometimes appears that a manufacturing and commercial policy frees a nation from this limitation, because, so long as an abundance of raw materials can be brought in from the outside, and all the finished products of the manufacturing industries can be marketed somewhere else, there seems to be no assignable limit to the amount which a nation can manufacture, if it only have labor and capital enough. That is to say, there always seems to be room enough for manufacturing and business sites. Land, from the national point of view, does not seem to be a limiting factor in these industries, though occasionally, in the narrower limits of a single city, land becomes scarce even for these purposes. But, as suggested above, this is a piecemeal view of the problem, for economic laws and principles are no more confined within national boundaries than they are within city walls. If all the industries, both rural and

urban, which are necessary for the full economic support of a self-sufficing population are considered without respect to national or municipal boundaries, it will be found that land is, in all civilized countries, a real limiting factor of production, which is the same as saying that the law of diminishing returns is everywhere in operaton where these conditions are considered.

Is there any occasion for alarm in this situation? Certainly not for us in the immediate future. From a scientific point of view, however, there are two things which ought to be said. In the first place, time is an element which may be left out of account. Whether the difficulties inherent in this situation will become acute in a hundred, a thousand or a million years, is not a matter of such importance as the question, are these difficulties inherent? In the second place, while we may not have any immediate cause for alarm, certain other people have, though that may not be our concern. The people of western Europe may not have had any cause for alarm in the days of Malthus, for the whole American continent lay before them. But the American Indians had ample cause for alarm had they understood the situation. Similarly, the civilized races of to-day may be at ease in Zion, their temporal salvation being assured, since South America and Africa lie open before them. But certain other races already in possession of those alluring Canaans may well be on the anxious seat, for their temporal damnation is imminent. It will be so easy for us to take these lands that, doubtless, it would be very foolish for us to worry about the land question. Fortunately, we are not the people who have to do the worrying, and doubtless a merciful providence has rendered the people who ought to worry incapable of seeing anything to worry about.

Since our growing agricultural population is showing a tendency, as all agricultural populations of the occident have shown for thousands of years, to spread rather than to remain pent up in their national boundaries, one of three things must happen if our population should continue to increase: (1) We must become more and more a manufacturing and commercial people, depending more and more upon the outside world for our agricultural produce, and joining in the general scramble of the commercial nations for outside markets; (2) we must restrain our people at home by force to prevent their emigration until the pressure of population upon subsistence becomes strong enough to check further increase and restore an equilibrium; or, (3) our people will spread over the territories occupied by inferior races, dispossessing them of their lands and sending them the way the Tasmanians have gone and the American Indians are going. Why are we compelled to face these alternatives? For no reason in the world except the law of diminishing returns, which, by the way, is reason enough.

RESEARCH IN MEDICINE[1]

By Professor RICHARD M. PEARCE
UNIVERSITY OF PENNSYLVANIA

I. Antiquity to 1800; The Efforts of Isolated Investigators

THE phrase "Research in Medicine" will naturally arouse different thoughts and associations in the minds of different groups of men.

The bacteriologist will be reminded of Pasteur, Koch, Behring and Flexner and the triumphs of bacteriology and serum-therapy; the surgeon, of Lister and antisepsis, of anesthesia, and of the X-ray; the physician of new means of cure and of diagnosis, of specific sera and vaccines, of the electrocardiograph, the polygraph and other complicated instruments of precision; and the average layman of a confused and confusing welter of catchwords and slogans for popular agitations vaguely associated with antitoxins, mosquitoes, good water supply, sewage disposal, lowered infant mortality and the modern treatment of tuberculosis. But in the last analysis the impressions of all would be of progress in a period representing a little more than half of the past century. This period is indeed the golden age of medical progress and one to which the historian or philosopher must give his best attention if he is to interpret, properly, the impulses which actuate medical research at the present time. That the earlier history of medicine is overshadowed by the rapid progress of modern discovery as represented in bacteriology is in the nature of things. But it should not, for that reason, be forgotten that the art of medicine existed before this period and with it much science. The pathologist, on second thought, reminds us of Morgagni and Rokitansky and the beginnings of pathological anatomy; the physiologist recalls Harvey and Haller; the surgeon mentions Ambroise Paré; the anatomist, after recalling many worthies, takes us back to Vesalius, to Galen and finally leaves us as does the internist, with Hippocrates, 400 years before Christ.

With this stretch of time and with these widely varying aspects of endeavor one must deal in attempting to present the story of research in medicine. It would be comparatively simple to chronicle the advance in any one field, as, for example, surgery, pathology or therapy; but this would, I fear, be less interesting and certainly not enlighten-

[1] These lectures were given as the annual Hitchcock lectures at the University of California. The foundation was created by Mr. Charles M. Hitchcock, who bequeathed to the University of California an endowment, the income of which was to be devoted to "free lectures upon scientific and practical subjects, but not for the advantage of any religious sect nor upon political subjects."

ing as to the full influence of research. The advantages to the community resulting from research in medicine are advantages because research has done away with conditions which were disadvantageous to the health, the happiness and prosperity of the community—in short such research has removed the impediments to a higher, happier and more prosperous civilization. It is necessary, therefore, in order to emphasize the importance of what has been accomplished, to portray the conditions of community life and individual hygiene, of medical practise and medical thought, and of science and philosophy at such periods as immediately precede definite advances in medical knowledge. The first of these lectures, then, bringing the story down to the beginning of the nineteenth century, will be presented from this point of view. The second lecture devoted to the influence of physics and chemistry, and the third to the rise of bacteriology, will outline the development of laboratory methods of investigation, the story, essentially, of medicine in the last half of the nineteenth century. The fourth lecture will be a survey of present-day methods and problems, and the fifth lecture will be a discussion of the position of medical research in America, its facilities, needs and opportunities, with special reference to medical research as a function of the university.

Of medicine in the earliest stages of its development we have no knowledge. Not until we arrive at a period of civilization as highly developed as that of the Assyrians and Egyptians do we find references to the practise—the studied practise—of medicine as a healing art. For all that precedes that period we must rely on analogy with medical practises among the aboriginal races to-day. But we can, nevertheless, safely assume that the healing art in all times, no matter how simple its form, was the practise of methods having for their object the relief of pain or the repair of injuries caused by mechanical means. Such methods must have been, at first, instinctive and empiric, or the result of chance observation. Some may, indeed, have been analogous to the methods which an animal adopts to cleanse a wound or protect an injured limb. The use of irritants, of emollients and of scarification, the binding of wounds, the mechanical support of a fracture and assistance in childbirth are primitive practises doubtless resulting from chance observation or experience. It is readily conceivable that the use of stone tools and weapons in hunting and in war may have originated the idea of intervention by operation; and that surgical dexterity may have increased proportionately to the improvement of weapons in the bronze age. Likewise it must be assumed that chance experience led to a knowledge of the action of the vegetable and mineral substances of the early materia medica. But of these beginnings we have no historical knowledge.

Our first authentic knowledge of medicine, fragmentary though it

is, is obtained from the cuneiform inscriptions which record the Babylonic-Assyrian civilization. These records are of a medicine controlled by the priesthood, closely linked to astrology and characterized by a belief in the influence of metaphysical forces, gods and demons. They do, however, contain references to the use of the knife in surgery, the healing of fractures and the internal administration of herbs, but all essential therapy is obscured by mysticism, ritual observances and magical formula. From the point of view of diagnosis, it is of interest that these records refer to the inspection of the urine and blood and to the collection of a series of observations upon disease, what we would now call the "clinical history" or record of a patient. These, however, were taken, not as to-day to aid in the diagnosis, but had the value of omens to aid the priest in his prophecy as to the outcome of the illness, or as we would say to aid prognosis. Such records were of little value, for without a knowledge of pathology—that is, of the underlying anatomical changes responsible for the symptoms—they were on the same level as astrological speculation and the interpretation of dreams. Inferences were not drawn from the empirical facts of clinical observations, but all observations were interpreted in the light of the supernatural, the ritualistic and the magical. This veil we find over all ancient medicine.

Egyptian medicine of a period 2,000 B.C. was much the same as the Assyrian, but the priestly science, as taught in the schools of the temples, developed a considerable knowledge of botany and zoology, without, however, an insight into the structure and functions of the human body. An extensive materia medica allowed the use of medicines as draughts, electuaries, gargles, snuffs, inhalations, salves, plasters, poultices, injections, suppositories, enemata and fumigations. As to general surgery, there is no evidence, aside from circumcision and castration, of operations other than those for the removal of surface tumors. Yet ophthalmology, otology and dentistry were known and practised as specialties. Obstetrics, on the other hand, does not appear to have been of interest to the physician. The hygiene of the Egyptians ranked higher than their therapeutics and included definite rules concerning meat inspection, bathing, clothing, diet, care of the dwelling and of infants. Indeed there is much ground for the belief that much of our modern hygiene can be traced back through Greek and Hebrew to the pioneer work of the ancient Egyptians.

Persian medicine is of little moment and differs but slightly from that of other ancient peoples in its religious-hygienic measures. One phase of religious belief was disastrous for the development of even simple empiricism—the belief that the dead and the diseased were unclean. Such a view naturally made impossible the study of anatomy and diagnosis. The sick, as unclean, were isolated, washed and purified

—a procedure which in our time we associate with good hygiene and the care of those suffering with contagious diseases; with the Persians, however, it was purely a religious form based on a belief in demons.

After the priestly hygiene of the Egyptians and Persians comes naturally, and probably sequentially, the social hygiene of the Old Testament. I need only remind you of the Mosaic laws, rational even in the light of modern science.

From the literature of antiquity much else might be cited to show the state of medicine among ancient peoples, the influence of religion, of primitive superstition and mysticism, all of which, however well-intentioned, prevented or obscured exact observation and deduction. The development of knowledge by observation and critical argument came slowly, and was possible only when the priest was no longer the physician. This great advance we associate with the period of Greek civilization and the name of Hippocrates.

Hippocrates may be considered in many ways, as physician, surgeon, philosopher and medical historian, but to one interested in the beginnings of research in medicine he is of importance as the first to record results based on observation, experiment and deduction, the tripod of the method of science. As a result, although much of his theory has been discarded, many of his procedures based on exact observation still stand the test of time and in many instances form the basis of modern methods. His age (470–361 B.C.) was the age of Pericles; contemporary with him, Thucydides wrote history, Phidias carved statues, Democritus originated his atomistic theory of the universe, and Socrates talked "human affairs" and "practical reason." That these men were real to one another is shown by the fact that Hippocrates was requested to declare Democritus insane and that Pericles died (429 B.C.) of the great plague which Hippocrates attempted to combat.

From this correlation of names it is evident that medicine shared in the general growth of Greek culture, and there is every evidence that Hippocrates was as great a representative of Greek intellect as were his contemporaries. Greece was at the height of its brilliant progress; it was, for the time being, the political, commercial, intellectual, scientific and artistic center of the universe. But among the Greeks the priests were not, fortunately for medicine, political or intellectual leaders; leadership was possessed first by the poets and later by the philosophers, and, under such circumstances, Greek medicine, freed of religious influence and fostered by philosophy, took a substantial form, and, though it contained much of generalized speculation, it had the solid foundation of unbiased observation. The former has perished under the influence of time and progress; the latter, resting on actual experience and genuine biological knowledge, remains. Of the methods of Hippocrates some idea may be obtained from the fact that he is

responsible for the very term "hypothesis," which, in its scientific application, he invented.

Some of the experiments of the Hippocratic schools may be considered as the first in the field of experimental physiology, as for example, the feeding at the same time of different kinds of food and the study, after induced vomiting, of the stage of digestion of each. It is, however, in the field of clinical observation that Hippocrates excelled. His inferences were frequently wrong, but his descriptions of the symptoms of a disease, as an aid to diagnosis and prognosis, were at once picturesque and accurate. How accurate and vivid they were may be seen from the fact that the characteristic signs of impending death are still known as the "facies Hippocrates." This exercise of minute observation and accurate interpretation of every symptom—the method of clinical medicine—which has influenced medicine in all succeeding ages, was the beginning of the study of what we now term the "natural history of disease." In therapy Hippocrates recognized the natural tendency to health (*vis medicatrix naturæ*) and this principle influenced all his therapeutic efforts. In addition to this substantial service to medicine we owe him certain idealistic influences as shown in the Hippocratic oath and in his constant desire to place all knowledge freely and fully before the profession at large.

Certainly medicine under Hippocrates, as contrasted with that of the preceding ages, was magnificent, and it is not surprising that after his death, he was deified. To us he represents the beginnings of an exact medicine, and his influence is seen in many of the theories, methods and ideals of modern practise. Hippocratic medicine, Hippocratic doctrine, Hippocratic oath, are current phrases, and the admonition "Back to Hippocrates" is an admonition to beware of theory and seek the solid ground of observation and experiment.

Between Hippocrates and Galen lie nearly five hundred years without progress in medicine, except as the brilliant Alexandrian school, sheltering Euclid, Archimedes and Ptolemy developed, under Herophilus and Erasistratus, a school of anatomy (ca. 300 B.C.) which established many new anatomical facts. But as Neuburger states in his discussion of early medical theories, "Collection and observation of facts constitute the first step in science, but not science itself." The observation of anatomical facts during these centuries is naturally of some importance in connection with the growth of anatomy, but unfortunately of no importance as regards the influence of those facts on medical theory, for physiology remained a field for speculation while the facts gained from anatomy were used only to strengthen the older speculation and dogmatism, and to rehabilitate discarded doctrines. To the Alexandrian school and to Galen, however, must be given the credit of a careful study of anatomy by dissection, and this honor is the

more deserved because, from Galen to Vesalius—a stretch of nearly fourteen hundred years—knowledge of anatomy was not advanced.

Galen (131–201 A.D.), a Greek, working in Rome, followed the traditions of the Alexandrian school in which he had been educated. He dissected freely a variety of animals, including, it is recorded, an elephant. It is, however, as an experimental physiologist that he brought new light to medicine. He supported the statements of the Alexandrian school, that nerves had motor and sensory functions, elaborated the theory of the control of muscles by nerves, and of the brain as the center of the nervous system, and, more important still, supported these convictions by well-planned ingenious experiments. His experiments on the brain and cord constitute the first experimental study of the cause of paralysis, and he thereby became cognizant of the fact that injury to one side of the brain affects the opposite side of the body. He established, again by experiment, that urine is secreted by the kidneys, and propounded the theory that the blood goes to the kidneys in order that the watery part may be filtered off. He studied the heart and its movements, recognized the fetal nature of the foramen ovale and the ductus arteriosus, wrote of aneurysm and practised the ligation of arteries.

Galen is the link between Hippocrates and Alexandrian anatomy, on the one hand, and Vesalius and Harvey, on the other.

> With his death and the passing of his immediate successors progress languished and expired, for the ancient world was dying and was bearing down with it the humaner arts. . . . For generations it seemed that the church alone had survived . . . cherishing ignorantly often, but jealously and fiercely, the records of a past science. (Mumford.)

The intellectual world of Rome, Alexandria and Constantinople was busied with theological controversies. The church became the arbiter of all knowledge and demanded that all science must conform to the Scriptures. Moral and intellectual progress became impossible. The political world survived the invasion of the barbarians, but the intellectual world was dying of dogma. For hundreds of years it was "first the soldier; second the priest; third the lawyer; fourth the merchant; fifth the physician; and then after a long interval the surgeon, ranking with the humblest of craftsmen." (Mumford.)

Nearly fourteen centuries pass after Galen before we can again take up the thread of progress. In these centuries—lost to science generally—the history of medicine shows but one isolated period of effort worthy of mention. This is that period represented by the Arabian school founded after the Mahommedan conquest and at its best from the ninth to twelfth centuries. This school represents no progress in anatomy, physiology or the general theory of medicine (which is to be explained by the fact that the religion of the Mussulman considers contact with a corpse sacrilege and thus debars dissection), but the

Arabs had an insight into chemistry, and, though they pursued their researches in the interests of alchemy and in the hope of finding the "elixir of life" or means of transmuting metals, they made, nevertheless, valuable chemical discoveries and in this way aided the art of pharmacy.

We therefore enter the sixteenth century of the christian era with little or nothing added during 2,000 years to Hippocrates's methods of exact observation in clinical medicine and surgery, with no decisive contribution to anatomy or experimental physiology for 1,300 years and with the beginnings of chemistry as applied to medicine and pharmacy removed by 600 years.

But despite this absence of real progress, a thin thread of learning and practise connected the medicine of Galen with the dawn of science in the middle ages. This is evident in the story of medicine in the monasteries and in the schools at Salerno and Montpellier in the twelfth century, but it is a medicine of the Roman period tinctured with magic and superstition and with no advance in theory or practise and certainly no increase in science.

The medicine associated with the revival of learning had its beginnings in the translation of Greek treatises on medicine through the Arabic; and in the early universities, especially those of Padua and Bologna and this revival of the exact methods of Hippocrates and Galen, gave to medicine a basis more substantial than the traditions of monastic medicine which had been perpetuated through ten centuries, and upon which were founded those widely scattered, but epoch-making advances which medicine reckons as its share in the general revival of literature, art and the sciences. With the name of Luther, Michael Angelo, Raphael, Titian, Copernicus, Columbus and Galileo we place those of Vesalius, Paré and Harvey. These names represent the period of the Renaissance, to which we look back with pride and satisfaction, but seldom with a thought of the conditions of home and community life. We are concerned usually with its deeds and achievements rather than with its social and hygiene conditions. But it is to the latter that I wish here briefly to direct attention.

The homes and habits of the people were filthy. As late as the sixteenth century in England, the streets of the populous cities were paved with straw and rushes, which soon broke up into powdered dust. Householders swept the filth of their apartments into the streets, and threw garbage there also, where, with the ground of rush and straw, a most intolerably filthy condition was produced, which rain modified, but did not remove. Moreover, people seldom bathed their bodies or washed their clothes. Besides, the food they ate contributed to disease. They lived chiefly on salt fish and flesh, with a modicum of stale vegetables. The domestic animals, the source of their meat, were herded in enclosures of the worst imaginable filth. Mutton was the chief flesh food of the people, but their flocks in cold season were herded in basements, partly underground, places without light and air except such as gained admittance from the door. Milch cows

were confined to these places also. The source of the food supply was, therefore, foul. . . . Places of public resort were without means of ventilation. The air of the churches was death-dealing, and made tolerable only by the fumes of incense. (Gorton.) Personal cleanliness was unknown; great officers of state, even dignitaries as high as the Archbishop of Canterbury, swarmed with vermin; such it is related was the condition of Thomas a' Becket, the antagonist of an English king. To conceal personal impurity, perfumes were necessarily and profusely used. The citizen clothed himself in leather, a garment, which, with its ever-accumulating impurity, might last for many years. . . . After night-fall the chamber shutters were thrown open, and slops unceremoniously emptied down. (Draper.)[1]

From the fourteenth to the sixteenth century plagues were frequent and attended with great mortality. Among the plagues known by various names as the "sweating sickness," "black death," etc., we are able to distinguish bubonic plague, typhus and small-pox. Likewise syphilis had been on the increase since the fifteenth century, and pre-

[1] The original upon which these statements are based I have been unable to obtain. Gorton's statement is evidently at second hand. C. Creighton in his "History of Epidemics in Great Britain" doubts the accuracy of the sweeping charges "of neglect of public hygiene" and "of lack of rudimentary instincts of cleanliness" in Plantagenet and Tudor times, but as careful a writer as F. Harrison gives in "The Meaning of History" the following summary of personal and community hygiene in the Middle Ages:

"The old Greek and Roman religion of external cleanness was turned into a sin. The outward and visible sign of sanctity now was to be unclean. No one was clean; but the devout Christian was unutterably foul. The tone of the Middle Ages in the matter of dirt was a form of mental disease. Cooped up in castles and walled cities, with narrow courts and sunless alleys, they would pass day and night in the same clothes, within the same airless, gloomy, windowless and pestiferous chambers; they would go to bed without night clothes, and sleep under uncleansed sheep-skins and frieze rugs; they would wear the same leather, fur and woolen garments for a lifetime, and even for successive generations; they ate their meals without forks, and covered up the orts with rushes; they flung their refuse out of the window into the street or piled it up in the back-yard; the streets were narrow, unpaved, crooked lanes through which, under the very palace turrets, men and beasts tramped knee-deep in noisome mire. This was at intervals varied with fetid rivulets and open cesspools; every church was crammed with rotting corpses and surrounded with graveyards, sodden with cadaveric liquids, and strewn with disinterred bones. Round these charnel houses and pestiferous churches were piled old decaying wooden houses, their sole air being these deadly exhalations, and their sole water supply being these polluted streams or wells dug in this reeking soil. Even in the palaces and castles of the rich the same bestial habits prevailed. Prisoners rotted in noisome dungeons under the banqueting hall; corpses were buried under the floor of the private chapel; scores of soldiers and attendants slept in gangs for months together in the same hall or guard-room where they ate and drank, played and fought. It is one of those problems which still remain for historians to solve—how the race ever survived the insanitary conditions of the Middle Ages, and still more how it was ever continued—what was the normal death-rate and the normal birth-rate of cities? The towns were no doubt maintained by immigration, and the rural labourer had the best chance of life, if he could manage to escape death by violence or famine."

sented a peculiar malignancy, and, like small-pox, attacked high and low alike. The causes and origin of these plagues are not difficult to find. Except for the Cloaca Maxima at Rome not a sewer of any consequence existed in Europe; drainage was inadequate, the streets were unpaved, and public baths or other facilities for bathing were unknown. Of sanitation no knowledge was at hand. The dead, including the victims of various plagues, were buried hastily—instead of being burned —and usually in shallow ditches, thus allowing presumably an easy pollution of water supplies. As to this, under ordinary circumstances no precautions were taken to keep the water supplies free from fecal and other contaminations. Doubtless, taxes on bread and window panes were responsible in no small part for that diminished resistance which invites infection. Against the spread of plagues the physicians were helpless. The College of Physicians at Paris in the fifteenth century at the time of the "sweating plague," were, after mature consideration, "of the opinion, that the constellations, with the aid of nature, strive, by virtue of their divine might, to protect and heal the human race." This state of mind does not seem so surprising when we recall that Roger Bacon, "the truest philosopher of the Middle Ages," still sought, in the thirteenth century, the philosopher's stone and the elixir of life. "The Royal Touch" was still a favorite cure for scrofula ("The Kings of Evil") and various other ills, and indeed persisted into the time of Queen Elizabeth. From "The Anatomy of Melancholy" (1621) we have it that "there be many mountebanks, quacksalves and empiricks, in every street almost, and in every village."

> Shall we, then, wonder that, in the famine of 1030, human flesh was cooked and sold; or that, in that of 1258, fifteen thousand persons died of hunger in London? Shall we wonder that, in some of the invasions of the plague, the deaths were so frightfully numerous that the living could hardly bury the dead? By that of 1348, which came from the east along the lines of commercial travel and spread all over Europe, one third of the population of France was destroyed. (Draper.)

Also, the condition of the insane was pitiable; until well into the eighteenth century they were imprisoned, chained and treated as wild beasts.

Rational therapy did not exist, though it is interesting to note that several important empiric specifics came gradually into general use, as mercury and sulphur introduced in 1510 by Paracelsus, sometimes termed "charlatan and bombast"; after Harvey's time, Dover's powder (*Pulvis Ipecacuanhæ* Comp.) through Captain Dover, physician and buccaneer; and *Cinchona* (quinine) through the Countess of Cinchon, wife of the Viceroy of Peru, who brought it to the attention (1638) of the Jesuit priests, hence the name, Jesuit's bark. Truly, empirical therapy made progress by curious routes.

Civil surgery was in a chaotic state, the barber surgeon contended

with the surgeon proper or "surgeon of the long robe" in the fields of minor surgery and both ranked far below the physician. In fact, surgery was largely abandoned to a class of ignorant barbers, bathers and bone-setters. Many operators were itinerant, going from city to city and frequently limiting their work to one or two kinds of operation, as that for cataract, or stone, or hernia. Military surgery without anesthesia or antisepsis was a horror of rough and ready emergency operations with boiling oil or heated iron as styptic and cautery, a torture beyond imagination. Indeed, to get an idea of the horrors of surgery in the lazaretto of the battle field even down to the year 1812, the date of Napoleon's descent upon Moscow, one needs but to read Tolstoy's work "War and Peace."

Thus we find the stage set for Vesalius and Paré, who with Hunter, though he entered somewhat later, laid the foundation, which, when anesthesia and antisepsis were added in the nineteenth century, gave surgery its right to claim a scientific basis. Vesalius, occupying a chair of surgery at Padua, developed anatomy as an exact observational science; indeed he may be considered as the founder of modern anatomical research. This was his great work; this and his influence in weakening the old speculative medicine and in establishing the principles of the scientific method. It was not an immediate influence, for upon the publication (1543) of his Fabrica Humani Corporis "the wrath of intrenched conservatism descended upon him" and he was forced to leave Padua, but his work was not in vain, for it hastened the development of surgical science and gave to anatomy the impetus necessary for its development as an observational science.

Ambroise Paré (1510–1590) began life as an humble barber-surgeon, and ended as the greatest surgical authority of Europe and the best loved man in France. (Mumford.)

Why the greatest authority? Because he went through the world with his eyes open. Why the best beloved? Because of his own unaided efforts he did away with more actual pain than has perhaps any other single individual except the discoverer of anesthesia. His methods were those of the practical clinician—observation as the basis of deduction unhampered by tradition. The story is told that Paré in his first military campaign followed the old custom which prescribed the use of boiling oil for all wounds. But after one severe engagement the oil gave out and he used, fearful of the consequences, a simple ointment. To his surprise he found that the wounds so treated healed more rapidly than under the old treatment. On this basis of simple observation and sound reasoning, he combated, against great opposition, the old treatment and established simple rules for the care of wounds. So also was it with the ligation of vessels after amputation. The custom had been to cauterize with the red-hot iron, the effect of which both physically and mentally it is not difficult to imagine. Paré reasoned

that as ligation of veins and arteries in simple wounds was possible, it was possible also at amputation, and at the first opportunity he demonstrated the correctness of his views. So by doing away with boiling oil and the heated iron he ranks among the greatest of humanitarians and, by establishing rational procedures for the treatment of wounds and for the ligation of vessels, as one of the greatest of surgeons.

Here it is well to depart from the chronological order and discuss John Hunter and his work and thus bring the advance in surgery to the year 1800. Between Paré and Hunter surgery was influenced by Haller and Harvey, but both these must be treated in detail in a consideration of other lines of activity. Suffice it to point out here that Harvey's work on the circulation of the blood and Malpighi's discovery of capillary circulation advanced surgery enormously by clearing up for the surgeon the mysteries of the blood-vascular system. The dread of hemorrhage had previously deterred surgeons from all operations except those of dire necessity or those in which the operation was in a gangrenous tissue. With this mystery of hemorrhage solved, the surgeon boldly ventured into new territory and rapidly extended the possibilities of his art.

John Hunter, pathologist, physiologist and surgeon, was active in the latter part of the eighteenth century. He worked in anatomy, comparative anatomy, physiology and surgery; essentially a laboratory investigator, "content" it is said "with four hours of sleep, scanty rations and little play." (Mumford.) Many were his contributions to anatomy, but his work on coagulation of the blood, inflammation and the repair of wounds, and, above all, the demonstration, that after ligation of vessels there occurs the establishment of a collateral circulation by anastomosis, were of the utmost importance to surgery. This latter, the basis of his famous operation for aneurism, was the result of a study of the growth of deer's antlers, in the course of which he tied one of the carotid arteries. To his surprise the cold antler of the ligated side, after two weeks, became warm. Dissection demonstrated that the ligature had not slipped, and on the basis of this observation he established those principles concerning the ligation of vessels in continuity so important in modern surgery. He also presented the first satisfactory explanation of inflammatory and thrombotic diseases of veins and contributed to the knowledge of gunshot wounds and of many other phases of medical science; but his great influence was the impetus which he gave to proper scientific research in medicine as well as surgery, in pathology as well as physiology.

To Hunter, the nineteenth century English school of surgery owes its fame, and in his honor the Royal College of Surgeons established the annual Hunterian Oration. After Hunter, and largely due to his influence, surgery advanced surely, though slowly, but without momen-

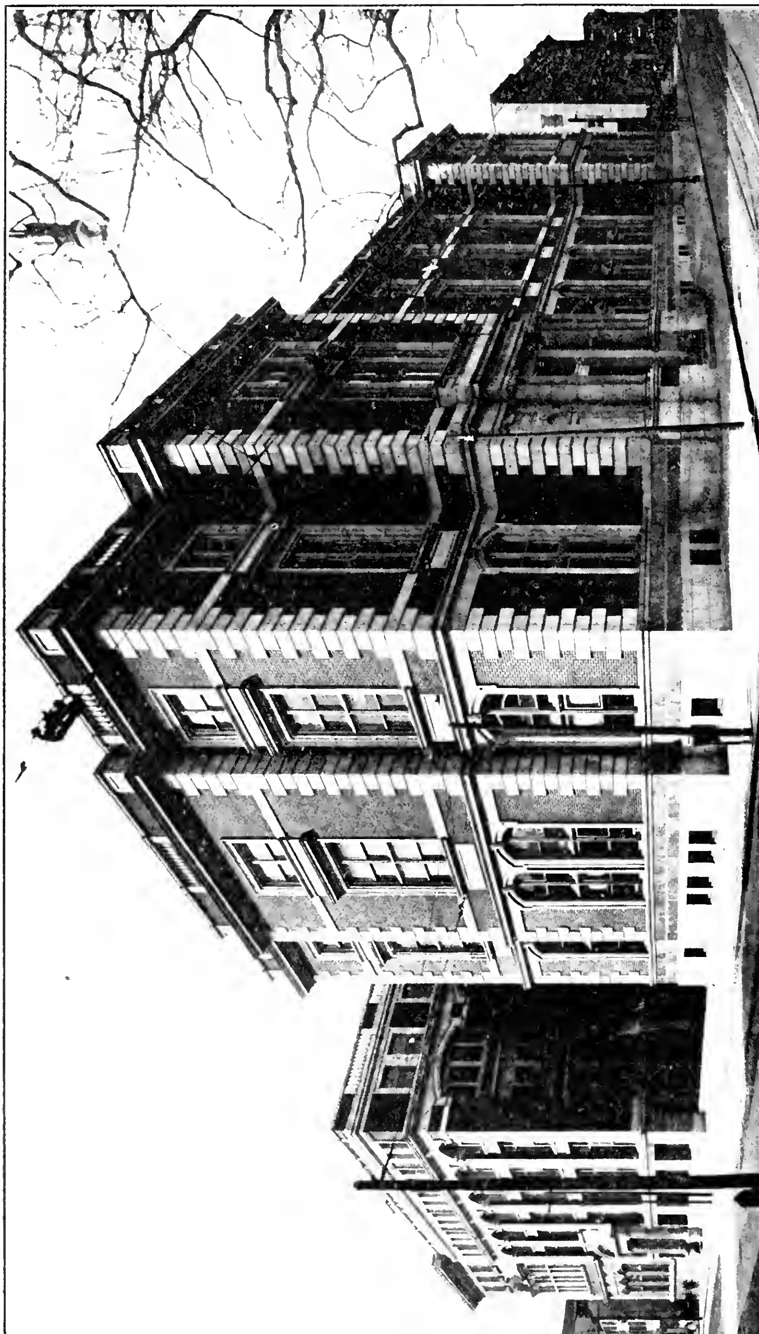
tous discoveries until the advent of anesthesia and asepsis in the middle of the nineteenth century. We may therefore leave surgery and turn to Harvey and events in physiology prior to 1800.

Harvey was of the Elizabethan period, a contemporary of Shakespeare, Milton, Dryden, Bacon, Descartes and Kepler. He studied at Cambridge and Padua and on his return to England, as Lumleian lecturer, gave most of his time to teaching and dissection. It was during the second year (1616) of such labors that he first propounded his theory of the circulation of the blood, but it was not until 1628 that his complete work on the subject was published. With the discussion as to the part played by his forerunners, by Servetus, Cæsalpinum and others in elucidating the mysteries of the circulation we are not now concerned. The honor of the establishment of the theory is Harvey's. More than this, it was the character of his exhaustive observations on a score of different animals (and on the heart of the chicken *in ovo*), his logical reasoning, and his convincing experiments that finally led to the correct solution and to the resurrection of a new method in medicine, that of experimental physiology. It may be remembered that Galen has been referred to as the first experimental physiologist; after fourteen hundred years he was followed by Harvey; then came Haller and Hunter, prophets of that modern experimental physiology which was in the nineteenth century to advance along all lines and to give to medicine a scientific foundation.

It is difficult to overestimate the significance of Harvey's discovery of the circulation of the blood. Sir Thomas Brown considered it greater than Columbus's discovery of America; Hunter ranked it with that of Columbus and that of Copernicus. Certainly it opened a new world in medicine. Progress, however, did not immediately follow Harvey's discovery, though four years after his death the capillary system, a link necessary to the completion of his doctrine of the circulation, was discovered by Malpighi. The period, was, however, one of detailed observation in anatomy, and despite the work of Malpighi and Borelli, experimental physiology languished until the time of Haller (1708–1777), who made additions to the knowledge of the mechanics of respiration, established the theory of irritability as a specific property of muscle and made important observations in embryology. How prophetic of the advances of the nineteenth century are the problems with which Haller and Hunter busied themselves. The study of the irritability of muscle suggests physiological instruments of precision, and embryology implies the compound microscope and the microtome, the familiar instruments of the latter nineteenth-century investigator in medicine. Hunter's problems—phlebitis, aneurism, syphilis, inflammation, the repair of wounds, the coagulation of the blood—remind one of many phases of present-day investigation. Prophetic also of the

phenomenal development of pathology, under Rokitansky and Virchow, was Morgagni's publication in 1761 of his "Seats and Causes of Disease," the first systematic effort to correlate clinical manifestations with pathological anatomy. Likewise, the introduction by Jenner (1796) of the systematic practise of vaccination against small-pox, presaged those methods of prophylaxis which within the next century were to revolutionize the methods of controlling many of the infectious diseases. We will return in later lectures to both Morgagni and Jenner and their influence on the development of pathology and immunology, but here they serve with Hunter and Haller to illustrate how a few individuals with a genius for accurate observation, sound thinking and exact experimentation may by their contributions foreshadow the activities of a succeeding century, and be the forerunners of new schools of thought. Their labors with those of Vesalius, Paré and Harvey are examples of that effort which, isolated though it was, during the three or four centuries preceding the year 1800 and proceeding as it did from individuals living and working in widely separated places, nevertheless, constituted in the sum a sound body of knowledge readily available to future investigators, equipped with new methods. With the exception of Paré no one of these men was thoroughly appreciated by his contemporaries. Vesalius was reviled and forced to leave Padua, Hunter's ligation of a vessel in continuity was at first ridiculed and Harvey's discovery, like others in various fields, because not possible at once of practical application, did not appeal to medical men who still clung to the traditional teachings of Galen. It was the period of genius working alone without the approval of the profession, without the support of universities and laboratories, and without the means of publications and the means of travel that to-day render almost immediately available new advances, achievements and theories. One had to journey to the city or country of this or that authority or investigator to get his views. Merz, in his "History of European Thought in the Nineteenth Century," gives, as examples of such voyages of discovery Voltaire's visit "to England in 1728, where he found the philosophy of Newton and Locke, at that time not known and therefore not properly appreciated in France; the journey of Adam Smith in 1765 to France, where he became acquainted with the economic system of Quesnay"; and the visit of "Wordsworth and Coleridge to Germany, whence the latter brought to England the new philosophy of Kant and Schelling." It is not surprising that under such circumstances advances in medicine, as in science generally, were few and far between.

How the change from individual to organized effort came about, and how medicine became the subject of investigation by scientific methods in laboratories established for that purpose will be shown in the next lecture.



THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

THE PROGRESS OF SCIENCE

THE CENTENARY OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

THE Academy of Natural Sciences of Philadelphia celebrated on March 19, 20 and 21 the centenary of its foundation, the last day being the actual date of the anniversary. On the first day Dr. S. G. Dixon, the president of the academy, gave a historical address and Dr. Edward J. Nolan, the secretary, gave reminiscences of the fifty years of his official connection with the academy. Delegates to the number of 147 presented letters, credentials and congratulations from the scientific and educational institutions which they represented. There was an important program of scientific papers. Dr. Dixon gave a reception on the second evening and on the third evening there was a banquet in the geological hall of the academy.

The centenary will be marked by the publication of a memorial volume, as well as the issue of a complete index of the academy publications, a work which has been under way for five years. The greatest memorial of the centenary, however, is the completion of the new buildings of the academy, which were temporarily put in shape for the celebration, but in whose new halls the great collections have not yet been fully installed. When finished, Philadelphia will possess in the group of buildings, which will face on one of the most important sections of the great Parkway, a museum of natural history admirably equipped in the way of collections, and in convenience of the exhibtion halls and of the research departments. Everything has been done by the president and the curators, utilizing the money appropriated by the state, to prepare a series of modern halls and rooms beautifully lighted both by day and by night, fireproof and meeting every demand of a modern museum. The result is an imposing group of buildings in brick, terra cotta and granite, with two entrances, one on Race Street, the principal entrance, and the other on Nineteenth Street, which gives access to the main service halls and the fine lecture room and the great library.

The new academy consists of three distinct buildings. The main buildings on Race Street, which replace the old historic centennial building of greenstone, is four stories high and is 184 feet long on Race Street, with a width of 64 feet. The first floor of this main building is given over to a large room with galleries supported by classic pillars, in which will be housed the great Vaux collection of minerals, and other mineralogical and geological treasures. Toward the Twentieth Street end, the valuable herbarium will be housed in the first and second stories, with the working rooms of the botanists arranged with the collections. In the archeological hall Mr. Clarence B. Moore's collection of Indian pottery will be the main feature, together with other collections relating to the history of mankind. Further south along the Nineteenth Street side are the lecture hall on the first floor and above it the great library and reading room. The book stacks are in the rear of the lecture hall, the reading room and the galleries, and run from the bottom to the top of the building. The library and lecture hall are really a separate building, protected by its construction from the menace of fire, its stacks representing the latest improvements and conveniences for the handling of the books.

On the second floor of the main building and the connecting wings there will be found the paleontological hall, 184 feet in length, with a width of 64 feet. This with its double galleries is the largest hall in the building. The connecting wing leading to the Nineteenth Street buildings will be given over to the Pennsylvania and New Jersey local collections, while the

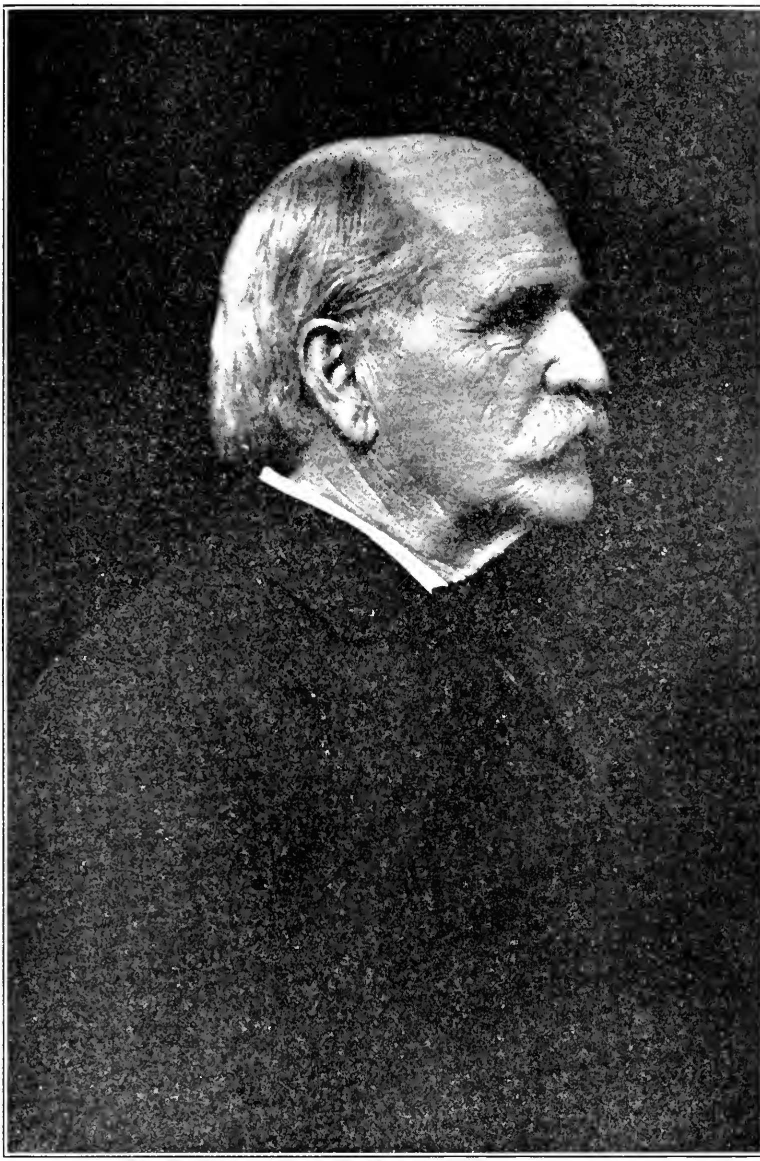
LIBRARY OF THE ACADEMY.

skeletons and mounted specimens of the mammals will be housed in the second story of the first building on Nineteenth Street, the third floor of which is given over to the large collection of birds. In the connecting wing of the third floor will be housed the entomological department, where over a million specimens will be kept in fire-proof metal cases, free from dust and moth. The fourth floor of the Race Street building will house the fine exhibition of shells, while the rest of the fourth floor of the buildings will be given over to the very complete working rooms of the scientific staff.

Within the last twenty years, under the presidency of Dr. S. G. Dixon, from an institution largely supported by voluntary membership, the academy has become an endowed institution with an annual income which maintains its work. No state aid has been granted to the academy for maintenance, but in view of the fact that it is the repository of the state geological collections, of very great value, within the last few years generous appropriations have been made for rebuilding, the space in the new buildings of the academy more than quadrupling the space in the old greenstone building in which so much work was accomplished for the advancement of science.

DEATHS AMONG AMERICAN MEN OF SCIENCE

THE hands of death have fallen heavily on our scientific men during the past month. When, earlier in the year Professor Brush died, we realized that, however great the grief may be, it is the way of nature for one who has passed his eightieth year and completed his life's work. Rear Admiral Melville, too, died full of years and honor. But the other deaths have been of men in mid-career, who go leaving unfinished the tasks which they only could do. These are Professors Rotch and Sanger, of Harvard University; Professors Montgomery and Spangler, of the University of Pennsylvania; Professor Smith, of Rutgers College, and Professor Tarr, of Cornell University. The oldest of them was but fifty-four,



George Jarvis Brush.

Formerly professor of mineralogy in Yale University and director of the Sheffield Scientific School.

the youngest thirty-nine. The scientific man, like others engaged in creative work, is likely to have his ideas early, but unlike the man of letters or the artist, he needs a full life to work them out. Science is long and slow, and becomes so increasingly with the accumulated heritage of knowledge.

Abbot Lawrence Rotch, dead after an operation for appendicitis at the age of fifty, was one of the few men of independent means in this country who have devoted themselves to science from love of the work. In 1906 he was given a partly honorary professorship at Harvard University, but twenty years before he had founded and had since directed the Blue Hill Meteorological Observatory, from which have come important explorations of the upper air by kites and balloons. Charles Robert Sanger, born in 1860, was director of the chemical laboratory of Harvard College. In spite of the onerous executive and teaching duties of the office, he found time to carry on accurate researches on the detection of minute quantities of arsenic, antimony and fluorine and on the chlorine derivatives of silicon and sulphur.

Thomas Harrison Montgomery, who died from pneumonia, barely thirty-nine years old, was in charge of zoology at the University of Pennsylvania, where there had just been completed under his direction a laboratory of zoology unsurpassed in the world. His researches on cellular structure and its relation to the phenomena of heredity and the determination of sex; on the activities, habits and development of spiders and birds; on the structure and development of various rotifers and insects and on the analysis of racial descent and of evolution, have been described in more than eighty monographs. Henry Wilson Spangler, like Montgomery, in charge of an important department of the University of Pennsylvania and of a large laboratory of mechanical engineering recently erected, died at the age of fifty-four. He was at the same time a distinguished engineer and a great teacher.

John Bernhardt Smith, born in 1858, was entomologist of New Jersey and of the Experiment Station as well as professor in Rutgers College. He had done important systematic work, but is best known for his economic work, especially on the suppression of the mosquito. Ralph Stockman Tarr, forty-eight years old at the time of his death, was professor of physical geography at Cornell University. He was distinguished for his work in physiography and glacial geography.

SCIENTIFIC ITEMS

Lord Lister bequeathed nearly the whole of his fortune to scientific institutions and hospitals, including $100,000 to the Lister Institute of Preventive Medicine and $50,000 to the Royal Society.—Professor A. Lawrence Rotch has by his will given the Blue Hill Meteorological Observatory with an endowment of $50,000 to Harvard University.

Dr. Ira Remsen has resigned the presidency of the Johns Hopkins University. It is understood, however, that he will retain the chair of chemistry which he has held since the opening of the institution in 1876.—Dr. George T. Moore has been elected director of the Missouri Botanical Garden to fill the vacancy caused by the resignation of Dr. William Trelease.

Sir J. J. Thomson has been appointed by King George V. a member of the order of merit. The other scientific men who are members of the order are Lord Rayleigh, Dr. A. R. Wallace and Sir William Crooks. The order has recently lost through death Sir Joseph Dalton Hooker and Lord Lister.—The second annual award of the Willard Gibbs Medal, founded by Mr. William A. Converse, will be made by the Chicago Section of the American Chemical Society on May 17, to Professor Theodore W. Richards, of Harvard University. It may be remembered that the initial award of this medal was made last May to Professor Svante Arrhenius.

THE POPULAR SCIENCE MONTHLY.

JUNE, 1912

TROPICAL SUNLIGHT[1]

BY DR. PAUL C. FREER

LATELY DIRECTOR OF THE BUREAU OF SCIENCE, MANILA

THE subject of the influence of sunlight in the tropics has been the subject of extended discussion for many years, and the general opinion seems to be that the intensity of insolation is the most important factor influencing the physical welfare of the white inhabitants in those parts of the world lying within the regions which are generally considered as having a tropical climate. In considering the question of what may be regarded as a tropical climate, we are too apt to be influenced by preconceived opinions as to what the dominating factors are, and we are prone to lose sight of the fact that there is as much difference between tropical climates as between those in the temperate zones.

Persons living in the tropics are almost certain, during their early years of residence, through ignorance or otherwise, radically to change their mode of living and subject themselves to hygienic conditions which they would consider inadmissible in their former homes. The races of people native to the tropical zones have no knowledge of bacteriology and pathology which would enable them to understand the measures to be taken to avoid infectious and other diseases, whereas they live in regions where the absence of a pronounced winter is favorable to the rich development of microscopical life. As a consequence, many of the ill effects which are attributed to sunlight may in reality be due to entirely different causes. Again, races native in the tropics, as a rule, do not have access to the complete food supplies of persons in temperate

[1] The manuscript of this article was received by the editor two weeks after the cabled announcement of the lamented death of Dr. Freer. Dr. Freer had attained high distinction as a chemist and since taking charge of the scientific work of the government in the Philippines in 1901, had contributed greatly to the organization and advancement of the scientific work under our government.

zones, although this statement may sound paradoxical, and this fact in turn may morphologically modify the peoples to a greater extent than other influences.

It can readily be understood that a place recognized to be within the tropics, may, by reason of its proximity to the sea, its altitude, relation to mountain chains, and other natural surroundings, have a climate so modified that the actual sunlight may have less influence than in localities which may be situated upon the borders or even within the temperate zones. Another factor influencing local conditions may be the color of the soil and the resulting modification of the intensity of the heat rays coming from it, because the radiation from the soil is of importance.

In other words, pronounced differences may be found between the climates of two places in the tropics which may geographically be close together, as may readily be seen by comparing the meteorological data from Alexandria, Cairo and Aswan, in Egypt. Prevailing winds may so modify the climate of a region that during the nights the temperatures may closely correspond to those found in places more favorably placed. Indeed, in comparing two regions we may find the anomaly that the tropical situation, for long periods, may have a more temperate climate than is found at the place nominally lying outside of the zone in question.

The general trend of the discussion in the literature has been that the rays of the sun lying in the region of the spectrum comprising the violet and ultraviolet are of the greatest importance in determining the influence of insolation upon human beings, and these rays have a special, though undeserved, designation as actinic rays. Studies of the influence of these rays have not been lacking; it has clearly been shown that they are destructive to great classes of microorganisms, and methods have also been devised to measure the relative proportion of these rays as compared with other parts of the spectrum. However, no thoroughly systematic work in this line has been carried out, and comparisons in the tropics are decidedly lacking.

Therefore it seems evident that the entire question of the influence of insolation upon the inhabitants of the tropics exists as a legitimate field for experimental study and that comparative data from different regions may be obtained so as to solve many of the questions in an impartial manner. The Bureau of Science at Manila is very fortunately situated in regard to this work. Its equipment is ample and the composite nature of the staff makes it possible to carry it on in a number of lines simultaneously. In addition, the newly organized University of the Philippines offers opportunity to call upon the faculty of that institution for cooperation. The opportunity being at hand, it seemed advisable to begin cooperative work on the subject of tropical sunlight,

and, therefore, about three years ago, several members of the staff from the two institutions undertook different lines of investigations with the object ultimately of coordinating the results into a monograph on the subject.

The first problem was to obtain data regarding the relative influence of the rays of shorter wave-length on different days and in different latitudes; and to obtain reliable figures, it was necessary to determine upon the photocatalytic reaction to be used. The decomposition of oxalic acid in the presence of uranyl salts, which is brought about almost entirely by the rays in the spectrum of the sun extending from 550 $\mu\mu$ to 291 $\mu\mu$, was decided upon. Although this method is not free from grave objections, which have been pointed out by me in another article,[2] nevertheless extended experimentation brought the decision that it was best adapted to the ends sought. Having decided upon the method and thoroughly learned the factors which influence the reaction, cooperation was requested in a number of laboratories in various parts of the world. The returns have not all been received, but so far extensive comparative measurements have been conducted in Manila (latitude 14° 36′), Kuala Lumpur in the Straits Settlements (latitude 3° 10′), Honolulu (latitude 21° 10′), Washington (38° 59′), Khartoum, Egypt (latitude 14° 36′), and a few data have been obtained from Tucson, Arizona (latitude 32° 12′). As yet, the returns from a number of other places have not been received. The results are surprising. In each one of the localities mentioned above, days of maximum insolation were observed which were practically identical, and in a number the averages were very close together. So, for example, at Manila the average percentage of oxalic acid decomposed for one hour during one year was 12.45; at Kuala Lumpur, 11 degrees farther south, 15.29; at Honolulu, 7 degrees farther north, 13.81, and at Khartoum in the Sudan, 17.6. The great differences do not lie in the averages obtained, but in the minimum observed on cloudy days. So, for example, both Kuala Lumpur and Khartoum show surprisingly uniform degrees of insolation, whereas in Manila and Honolulu the proportion of cloudy days is so great as to bring the average down materially. In Manila the minimum observed was 1.15; in Honolulu, 3.48; whereas at Kuala Lumpur the same figure was 9, and at Khartoum 14.7. Therefore, the difference of climate of these places is not due to geographical location, but is purely a meteorological phenomena. Washington, with a winter climate and presumably much greater atmospheric disturbances, on the entire average gave about 33 per cent. less decomposition than Manila, yet the maxima are practically the same and at times Washington shows an astonishingly high average, and there is but little difference between the summer and winter months in the latter place.

[2] *Phil. Journ. Sci.*, Sec. B. (1912), 7, 1.

As mentioned above, we have but few data from Tucson and, therefore, at present we can scarcely make a comparison, but doubtless when a longer series of observation is at hand we shall discover that there are many days in Tucson showing a maximum as high or even higher than Manila, and an average of about the same. The fact is also observed that two days apparently equally clear will show marked differences between each other during corresponding hours, so that the proportion of the rays reaching the earth and lying between 550 $\mu\mu$ and 291 $\mu\mu$ varies from day to day. A comparison of the total effect of these rays with the measurements obtained by the black bulb thermometer also demonstrates that the two are not functions of each other. Of course it is clear that there must be a certain relationship because, obviously, on clear days both black bulb readings and photocatalytic measurements will be high, but they need not necessarily be high in the same proportion. The sun's rays which lie in the portion of the spectrum under discussion, on reaching the atmosphere, suffer molecular scattering, refraction and other changes which modify the proportion of direct sunlight that reaches the earth's surface, and, of course, these changes vary with the condition of the atmosphere. Nevertheless, it is very interesting to observe that even in the tropics the shortest wave-lengths appearing in the spectrum of the sunlight are very close to 291 $\mu\mu$ and that no shorter rays reach the surface of the earth. The same observation was made in northern latitudes, so that it can confidently be stated that the range of the spectrum everywhere is the same, the difference, if any, being in the intensity of the light.

The average of the measurements made at Baguio, which lies a little north of Manila at an altitude of 1,432 meters, shows that the photocatalytic action of the sun in that locality is much the same as it is in the lowlands. The maximum is slightly higher, being practically identical with that of Honolulu, and the average is 1.75 per cent. more than in Manila, and 1.09 less than at Kuala Lumpur, and 0.39 more than Honolulu, so that the ascent of 1,432 meters has produced the same effect upon the photocatalysis as would a transfer from Manila to Honolulu.

The above is a very brief summary of the results so far obtained in a study of photocatalytic reaction brought about between the rays lying between 550 and 291 $\mu\mu$, and in view of the results the more extensive remainder of the spectrum, which extends upward from the point mentioned into the red and infra-red and which would include the heat rays, must be considered. It is self-evident that comparative measurements in this field involve much greater difficulties, as, at present, no photocatalytic reaction is available. The best means at hand is by a comparison of a series of readings with the Angström pyrheliometer of

the total solar radiation per square centimeter of surface normal to the ray of incidence.

Unfortunately, measurements in the tropics with this instrument are lacking and in Manila we have not yet been able to carry them out, because the instruments which we have ordered have suffered great delays in delivery. A large number of available data have been gathered by Dr. Herbert H. Kimball, of the Mount Weather Observatory, and comparisons of the maximum intensity of solar radiation extending from Cape Horn, on the south, to Treurenburg, on the north, show that the variations are not great and those which appear, in the belief of Kimball, are due to instrumental errors rather than to atmospheric conditions. Angström gave some measurements from Teneriffe (20° 30′ north) and obtained practically the same figures as those quoted by Kimball. Dr. Rudolph Schneider in February, in Vienna, found a maximum higher than that given for Cape Horn and practically the same as that at Katherinenburg, and the observations made by him for the time close to the noon hour show a close resemblance to those in Washington. Harvey N. Davis, of Providence, Rhode Island, obtained practically the same results. Kimball, in discussing the annual march of radiation, as compiled by him, states that "a rather surprising uniformity throughout the year (is shown) in the maximum intensity of radiation, the December minimum being only 8 per cent. less than the April maximum." Even if we take the annual total we find that Warsaw actually has 85 per cent. of the radiation received at Washington, although it is 20 degrees farther north.

Because data with the Angström pyrheliometer in the tropics were lacking, we had recourse to animal experiments in Manila. In this connection it should be remembered that although air temperatures in some regions may be low and in others high, the effect of the sunlight on solid objects, as in the case of the black-bulb thermometer, may be very great and bear no relation to the shade temperature; so, for example, Davos, Switzerland, shows an average maximum black-bulb thermometer reading for three years of 53°.8 with a highest absolute maximum of 67° in 1910, whereas the maximum in Manila in one year was 56° and at Helwan, Egypt, 70°.8 during a period of three years. Alexandria during the same period gave 57°, Aswan Reservoir in June, 1910, showed a maximum of 81°, and Ley, Thibet, with an altitude of 3,517 meters, a maximum black-bulb thermometer reading of 101°.7 with a shade temperature of 23°.9. These figures refer to maxima only and do not take into consideration averages or the shade temperatures which might be high or low, but it is evident that the occurrence of days of extreme insolation is not so much a matter of latitude as of situation and it is evident that even in the tropics we might come to averages decidedly lower than in certain more northern climates. It is obvious

that in any one of the places mentioned and which lies outside the tropics, a living body might encounter days in which it would be heated by solar radiation to a much greater extent than in the tropics, and the only question would be whether the possibility of cooling, such as low air temperature, low humidity, winds or other means would compensate to avoid the effects of such insolation.

Our studies were undertaken with animals having fairly well developed means of heat regulation. The most interesting results were obtained with monkeys and human beings. To obtain comparable data, means had to be devised to give accurate and rapid measurements of the temperatures of the skin and of the inner parts of the body, and eventually a very satisfactory apparatus was completed by Dr. Hans Aron, of the department of physiology of the College of Medicine and Surgery, which gave the temperatures by means of specially prepared thermocouples, the changes being read by a tangent galvanometer. Monkeys are naturally at home in the tropics, and we should suppose that they would best be able to withstand the effect of sunlight. They have a system of sweat glands, but this is not so highly organized as it is in man, so that their physical heat regulation is brought about not only by evaporation of sweat, but also to a very great extent by water evaporated from the lungs and mouth through increased respiration. If a monkey is exposed to the sunlight in Manila, his subcutaneous and rectal temperatures rise rapidly, the former more rapidly than the latter, and the animal will die within 1 hour and 20 minutes to 1 hour and 50 minutes, the temperatures gradually reaching maxima. Entirely different results are obtained if the animals are shaded, even by such a small area as is produced by an umbrella or a piece of board, all other conditions being similar, except that the direct rays are excluded. Under these circumstances the skin and rectal temperatures never exceed 40° and the animals remain healthy. Similar results are obtained if the animals are exposed to full insolation, but care is taken to conduct away the excessive heat increment by means of a brisk current of air from a fan. Under these circumstances the subcutaneous and rectal temperatures remain the same as when the animal is shaded. In this form of experiment the monkey is exposed to all the rays of the sun, including those of lesser refrangibility, heat waves alone being conducted away. If untoward effects are to be attributed to the absorption of the ultraviolet rays, then surely the animal is in the same condition to absorb the latter as he is when no blast of air is present, and their effect should be apparent. On absorption, a large proportion of these rays is presumably converted to heat and conducted away as such, so that it can be assumed that the effects which we observe on exposing these animals to the sun is one of heat, and these conclusions are borne out at autopsy where post-mortem examinations give protocols clearly

pointing to heat stroke. Monkeys enclosed in tight boxes, with only the heads exposed, and placed in the full sun, suffer no inconvenience, although the hair temperature on the scalp may reach 47°. Of course, it must be understood that the monkey's skin is protected by fur and is not sensitive to the irritating effects of the ultraviolet rays as would be the case with the skin of a Caucasian, who, if exposed to the sun, would be sunburnt, whether in a strong blast of air or not. This latter effect is due to the ultraviolet portion of the spectrum, and, as these rays have but little power of penetration, the skin can in time amply protect itself by pigmentation. But even though protected, as is the monkey's skin, and hence not subject to sunburn, the heat effect still remains and brings about the results of excessive heat exposure.

Experiments on man have shown that the ultraviolet rays are easily guarded against, by shade or even by a white cotton shirt, the heat rays not. In man we have a subject with highly developed sweat glands, so that the means of heat regulation by evaporation are much more complete than in dogs, rabbits or monkeys.

Skin temperatures of men in this climate in the shade under normal conditions, as measured by our apparatus, vary within the extreme limits of 31° to 34°. On exposure to the sun, these temperatures rise rapidly on the sunny side, but as soon as the human subject begins to sweat, even slightly, the temperature begins to fall, and with muscular exertion may be as low as 31–33°. If the subject is at rest, the skin temperatures do not fall as rapidly, but after one hour they may be the same as at the beginning of the experiment or even more than a degree lower. In going over our long series of figures we found that fifty minutes of exposure caused no practical rise over the temperatures after the first ten minutes in white men and in Malays.

The comparison showed but little difference between the white and the Malay, the difference, if any, being in favor of the latter, but a Negro, in a series of observations, exposed to the sun at the same time as a blond European and a brown Igorot, showed a higher skin temperature by 1°.45 than the Caucasian. At the end of the experiment the final temperatures were decidedly against the Negro, slightly against the Tagalog, and in favor of the white skin. Therefore, so far as they have gone, our experiments seem to show, as regards rise in temperature upon exposure to the sun, that the white and brown skins are about equal, with a slight factor in favor of the white, but that in the case of the very dark-skinned Negro the temperature, on exposure, reaches a decidedly higher point than it does with either of the others. The dark skin of the Negro obviously will absorb heat more readily than the lighter one of the European, and also will radiate more readily, the heat taken up on the sunny side being rapidly lost on the shady one; but this balance evidently results in a greater rise of temperature for

the Negro than for the white man. With the white skin we have the phenomenon of sunburn, with its resultant irritation of the nerve-endings and hyperemia of the peripheral tissues, and this will cause a rise which, apparently, just about offsets the rise in the pigmented brown skin due to the sunlight. To determine definitely the decided difference brought about by the color of the subjects, it was decided to use experimental animals which would show great contrasts; and white, gray and black rabbits gave the data sought. I will select one experiment. When exposed side by side to the sun, the black rabbit reached a maximum subcutaneous temperature of 47°.8 in thirty-one minutes and then died; the gray rabbit a final temperature of 44°.9 in one hour and twenty-six minutes and then died; the white rabbit a final temperature of 45°.7 and when put in the shade it recovered, although much exhausted. None of the animals suffer from sunburn as does the white man, and it is evident that the darker the coat, the greater the heat absorption and the more apparent do the effects of insolation become.

These experiments bring us to the conclusion that, all other things being equal, the Negro will suffer more from the heat effects of the sun than the lighter-skinned races, and all of the work tends to show that the rays of greater refrangibility in the violet and ultraviolet portions of the spectrum are not the important factors, except in so far as they cause sunburn and subsequent excessive pigmentation. However, protection from these rays is easily accomplished and has been accomplished so long as man has worn clothes. These experiments also show that the whiter the clothing the better it is adapted for protection against sunlight and that even in the tropics, if care is taken to seek the shade, no untoward effects can be observed. Indeed, Major W. P. Chamberlain, United States Army Medical Corps, who investigated the systolic blood pressure of a large number of residents in the Philippines, concluded that there is no progressive tendency for the pressure to increase or to decrease with a continued tropical residence covering periods of over three years, beyond which length of time his observations do not extend.

From all of our present studies it would seem legitimate to draw the conclusion that a climate such as we have in the Philippines, where we are surrounded by the sea which modifies the extreme of temperatures and where we have such a large proportion of cloud, is not by any means deleterious to the white man if he takes ordinary precautions which are not as elaborate as those he would take in a northern climate to keep out the cold. In the Philippines the nights are rarely too hot for comfort; they may even be quite cool.

The actual number of hours of insolation per year on the earth's surface, were the sky always clear, is greatest at the equator and diminishes toward the poles, the ratio between 0° and 45° being 1.83 to 1.34,

although in the longer days in the temperate zone the sunshine reaching the earth when the sun is near sunrise or sunset is only a small proportion of that at midday. As a result we have in the tropics greater absorption and radiation from the earth's surface as a result of direct exposure to the sunlight to augment the influence of the sun's rays, so that, as it has been shown that the heat factor is the chief one to consider, this increment due to radiation from the earth will be of decided influence. This will naturally vary with different regions according to the hours and intensity of insolation and the color of the surface exposed, being least with green surfaces of vegetation and greatest with rocks, or red, clay soil, such as is common in India under the name of laterite.

Another factor needs to be considered, and that is the evenness of the tropical climate, which is devoid of severe contrasts, such as are given by the winters in northern climates, yet Chamberlain's results seem to indicate that this has but little effect.

I have endeavored in this short article to give a very brief résumé of the most important points which, up to the present, have been brought out. Any one can see that the subject under investigation is so complex and that it is influenced by so many factors that general conclusions at the present time are premature, excepting in so far as they are borne out by experimental evidence. Obviously relative humidity is of great influence on evaporation and varies with geographical locality, the season of the year, and other causes. Experiments carried on in Manila also seem to show that the Malay and the Negro possess relatively more sweat-glands than the European. The formation of ions in the air, the proportion of such ions, if any, due to the effect of the sunlight, and the total ionization brought about by radioactivity may be of influence in controlling the electro and other meteorological phenomena, and we have also begun work in this direction, but as yet are not in a position to publish the results.

Although the spectrum of the sun, as shown by the spectrograph, does not extend beyond 291 $\mu\mu$, still it may be possible that we receive rays the nature of which we have not yet determined and which, with our present physical technique, we can not determine. These may also be factors in the phenomena of insolation.

Photograph by Bailey Willis.

MOUNT SIYEH, SCENE UP CANYON CREEK, NEAR ALTYN, MONTANA. GLACIER NATIONAL PARK.

THE NATIONAL PARKS FROM THE SCIENTIFIC AND EDUCATIONAL SIDE

By LAURENCE F. SCHMECKEBIER

WASHINGTON, D. C.

THE passage of the act of Congress creating the first national park —the Yellowstone—was due in large measure to the interest and activity of the chief geologist of the Geological and Geographical Survey of the Territories, Dr. F. V. Hayden, and in the forty years that have elapsed since the creation of that great reservation the wonders of the national parks have claimed the attention of workers in every branch of science. As might naturally be expected, the more extensive scientific work in the parks has been in the field of geology and its allied sciences, because the wonderful forms of nature which have been the main factors in inducing congress to create these parks are the result of forces whose study falls particularly within the realm of geology. In the Yellowstone Park the geysers, the hot springs, the terraces, the fossil forests and the Grand Canyon of the Yellowstone River present absorbing and instructive geologic problems; in the Mount Rainier National Park is one of the largest glacial systems known to radiate from a single peak: in the Crater Lake National Park is the only lake in the United States that is situated in the caldera of an extinct volcano; in the Yosemite National Park the great gorge of Yosemite Valley presents perplexing problems to the student of physiography and widely divergent theories have been advanced regarding its origin; in the Glacier National Park are over 80 glaciers varying from a few yards to five acres in extent that have received practically no attention from the student of glaciology. But geology can not lay claim to the entire field. At the Hot Springs Reservation of Arkansas the healing waters are of great interest to the chemist and physician as well as to the geologist, and in the Mesa Verde National Park the remains of the vanished race of cliff dwellers offer a prolific field to the ethnologist and anthropologist. In the Yellowstone, Mount Rainier, Crater, Yosemite, Sequoia and General Grant Parks there is a prolific flora of native trees, flowers and grasses such as can be seen in few places in the west. In all the parks the protection of the game affords opportunity for the study of many faunal species that have been almost exterminated except in these reservations.

The scientific bureaus of the government and various learned societies have issued publications on the parks that are accessible to the

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HEAD OF LAKE ST. MARY, GLACIER NATIONAL PARK.

scientific traveler who knows where to look for data and who has access to the libraries in which these publications are deposited. But to

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ICEBERG LAKE, GLACIER NATIONAL PARK.

the tourist or the teacher who does not have access to large collections neither the government nor the scientific societies have offered any assistance in his search for information. The publications either are not generally available or are so voluminous and technical that the general reader is repelled rather than encouraged to seek information.

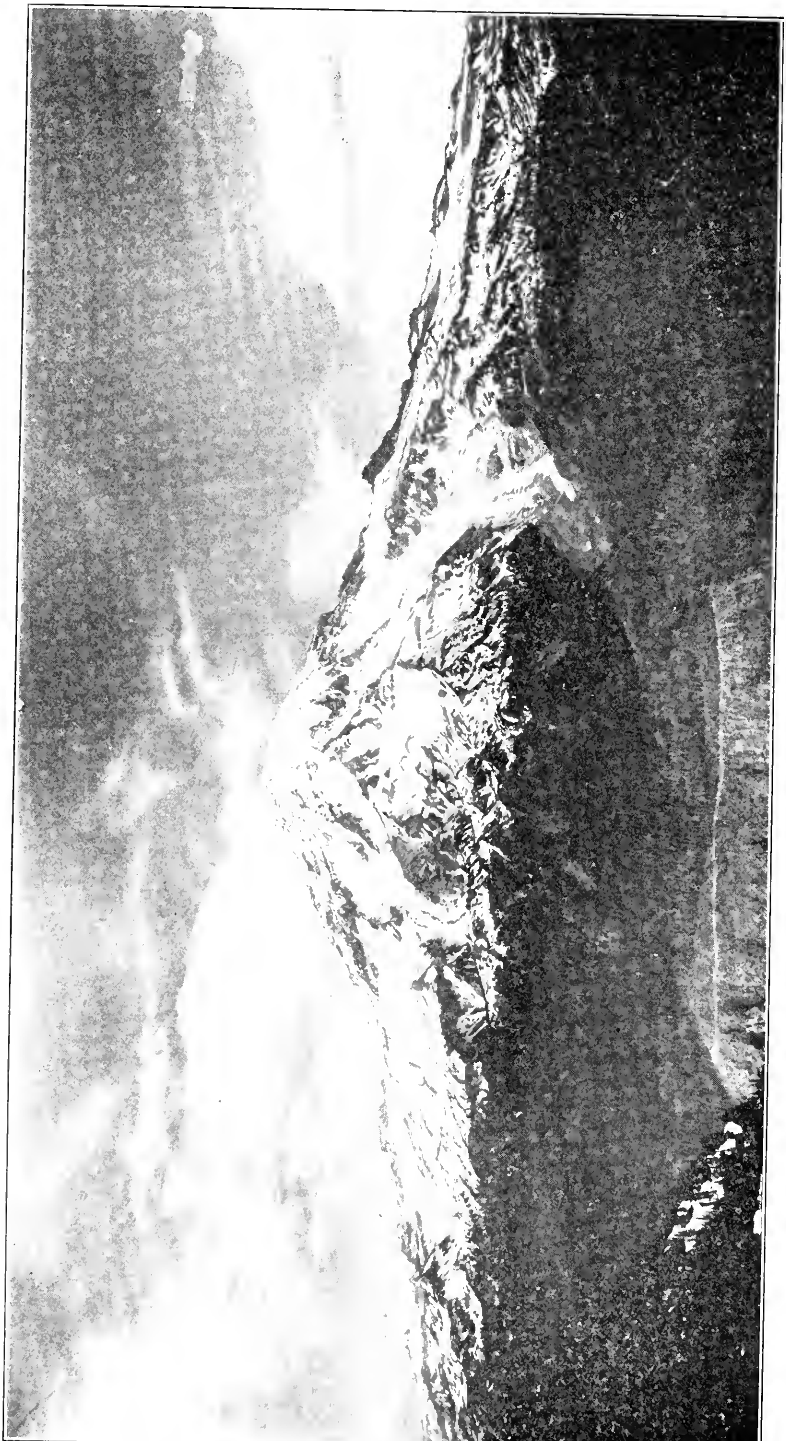
During the season of 1911 over 90,000 persons visited the national parks, not including the visitors to the Hot Springs of Arkansas. The majority of these tourists are intelligent and educated people anxious to learn something about the causes underlying the wonders they are witnessing. Every one who has seen the beautiful and brilliant pools

Photograph by Asahel Curtis.

PARADISE PARK AND MOUNT RAINIER.

in the Yellowstone Park is at least curious to know the cause of the harmonious and delicate coloring. The guides and stage drivers generally state that the colors are due to mineral matter, and as most people usually associate color with mineral the tourist goes home fully convinced, when as a matter of fact the color in the pools is due to the growth of algæ, as has been conclusively shown by Mr. Hague and Mr. Weed.

The officers of the Department of the Interior, which has charge of the national parks, have reached the conclusion that a series of short scientific publications on the parks will not only add to the pleasure of



Photograph by Asahel Curtis.

MOUNT RANIER, GAP POINT AND PARADISE VALLEY.

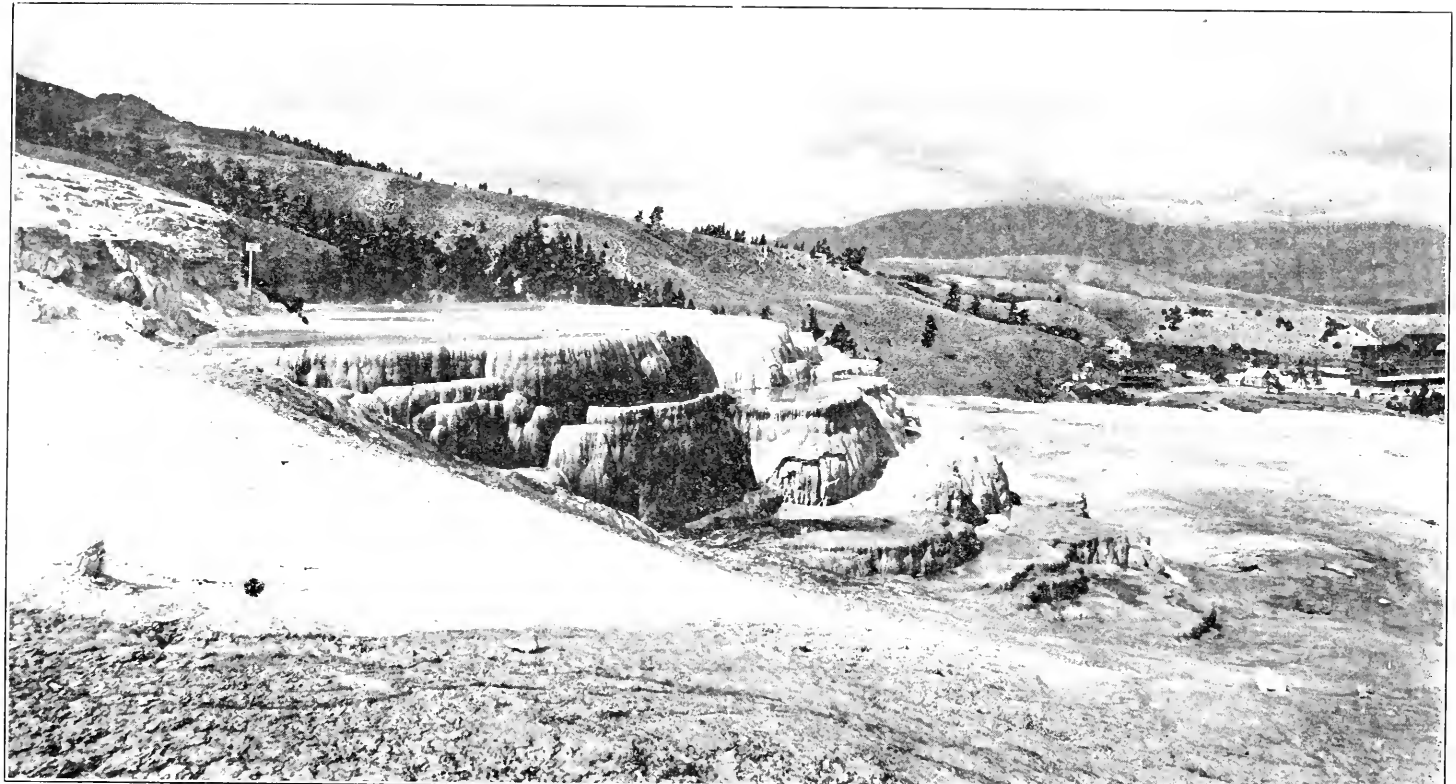
the tourist but serve an extremely useful educational purpose by disseminating the results of scientific work. It is therefore planned to issue a number of short publications describing the phenomena in the various parks and explaining the causes and forces that have produced them. It is not contemplated that the department will embark on original investigations, as it is believed that more material can be obtained than can be printed with the funds available, but it is hoped to revise some of the papers already published and issue them in pamphlet form. The department has just issued the following publications: "Geo-

Photograph by Asahel Curtis.

MOUNT RAINIER, FROM KAUTZ FORK. MOUNT RAINIER NATIONAL PARK.

logic History of the Yellowstone Park," by Arnold Hague; an account of the geysers of the Yellowstone Park, including a comparison with the geysers in New Zealand and Iceland, by Walter Harvey Weed, and the geologic history of Crater Lake, by Joseph S. Diller. These publications are illustrated with well-selected half-tones and carefully prepared black and white maps based on the accurate topographic maps issued by the Geological Survey.

The first need of the intelligent traveler is a map of the area he is about to traverse. Fortunately excellent maps of almost all the larger parks are for sale by the United States Geological Survey at nominal prices. Maps have been published of Yellowstone, Yosemite and Glacier national parks on a scale of 2 miles to the inch; of the Crater



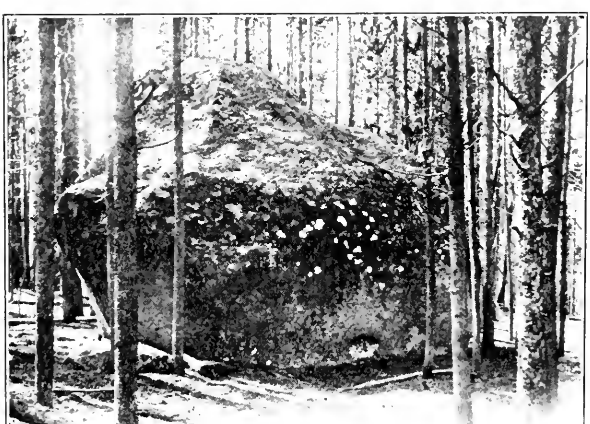
Photograph by J. K. Hillers.

Hot Spring, Yellowstone National Park.

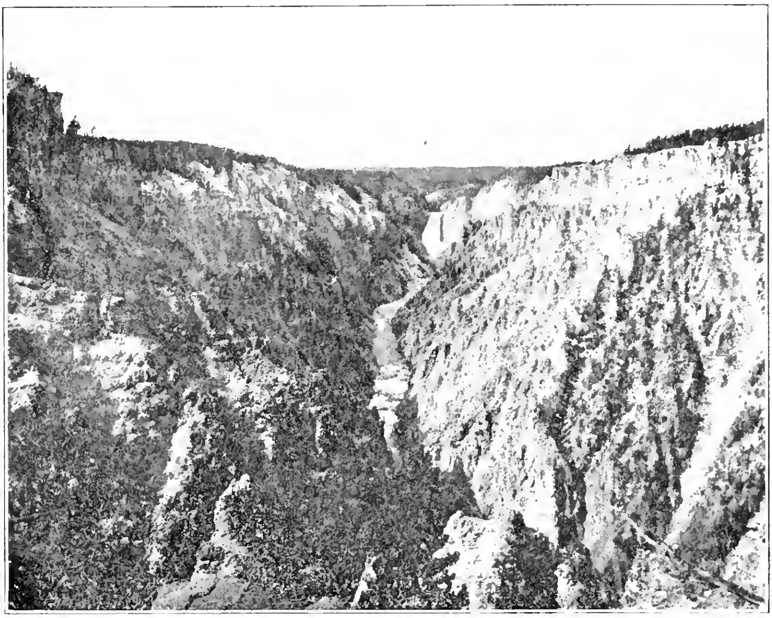
These terraces are composed of nearly pure travertine that has been deposited by the waters from the hot springs.

MOUTH OF FOUNTAIN GEYSER, YELLOWSTONE NATIONAL PARK.

Lake Park on a scale of one mile to the inch and of Yosemite Valley on a scale of 2,000 feet to the inch. Separate maps of the Sequoia and General Grant parks have not been published, but the topography of these parks is shown on the regular atlas sheets issued by the Geological Survey. A part of the field work has been completed on the maps of the Mount Rainier and Mesa Verde national parks and the surveys will be finished during the coming summer. These maps should be ready for the season of 1913. All of these maps are in three colors, the drainage being shown in blue, the relief in brown and the culture or works of man in black. In addition the Department of the Interior has prepared tourist-travel maps of the Yosemite, Yellowstone, Glacier, Crater Lake, Sequoia and General Grant national parks. These maps will be in black only and will be used as double-page illustrations in

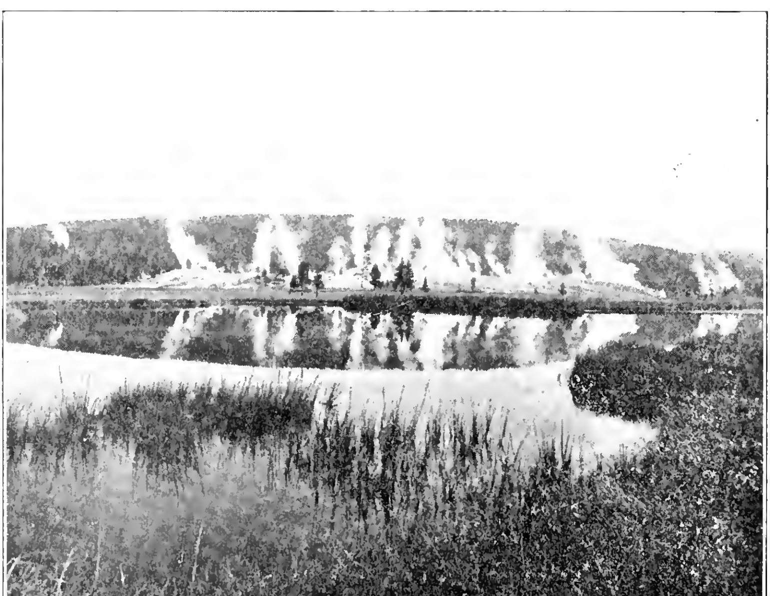


GLACIAL BOULDER, YELLOWSTONE NATIONAL PARK.



GRAND CANYON OF THE YELLOWSTONE.

some of the pamphlets in preparation. While they have been carefully prepared they are not intended to be substitutes for the more expensive and elaborate maps printed in colors.

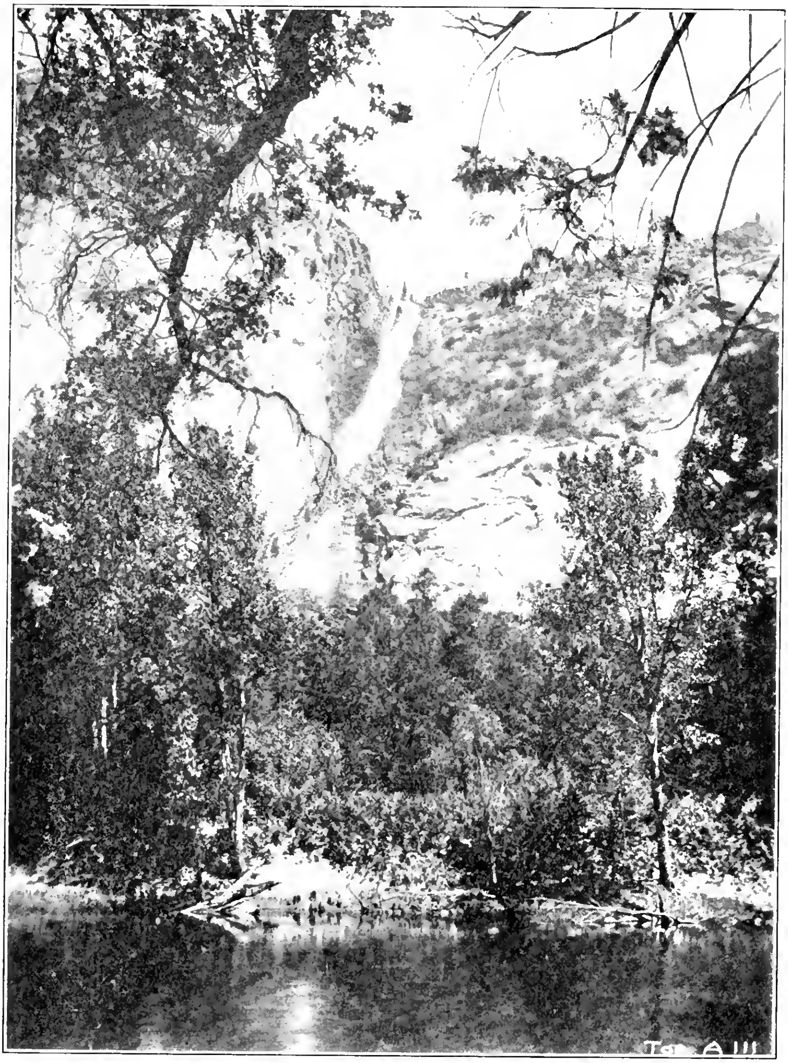


UPPER GEYSER BASIN, YELLOWSTONE NATIONAL PARK.

Photograph by H. C. Best.

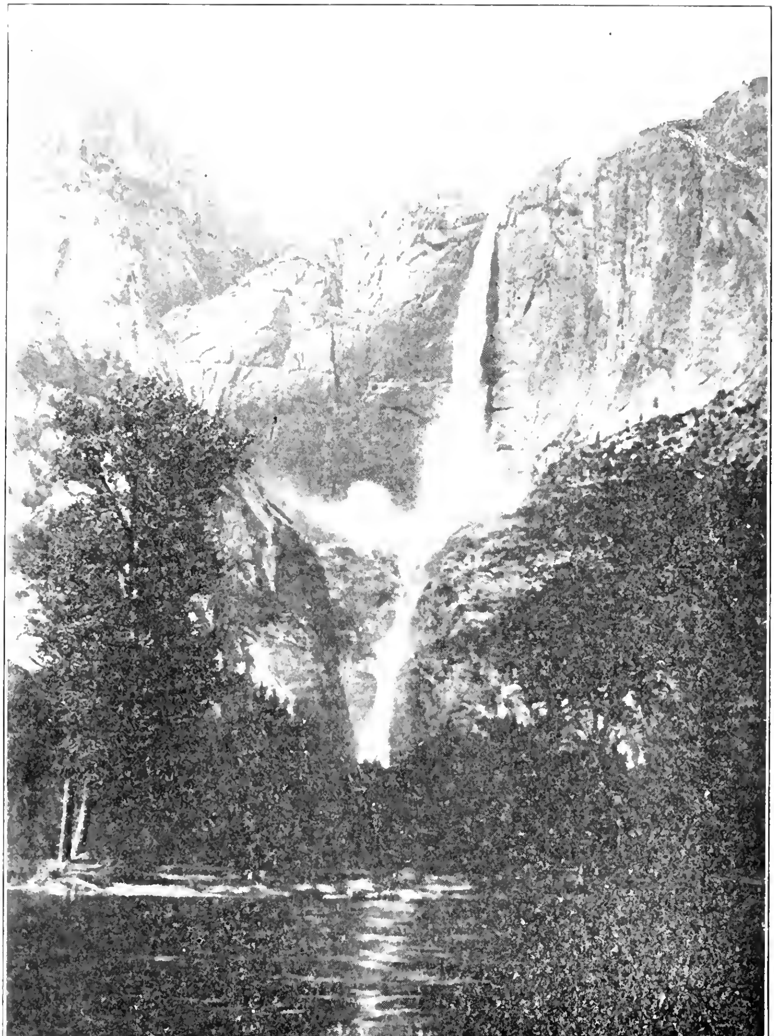
YOSEMITE VALLEY FROM MORAN'S POINT.

In addition to the descriptive articles it is proposed to issue short pamphlets on each park for the benefit of the traveler. These folders will give general information regarding the railroads tributary to the parks, the methods of transportation available within the parks, the location of hotels and camps, and the rates that are authorized for all classes of service. As the government does not operate any hotels, camps or stage lines in any of the parks, all these privileges being granted to corporations or individuals under term contracts or annual permits, this information will be published so that the traveler may intelligently plan his trip.



WAPAMA FALLS, south side of Tuolumne River, in the foreground Hetch Hetchy Valley, Yosemite National Park, Cal.

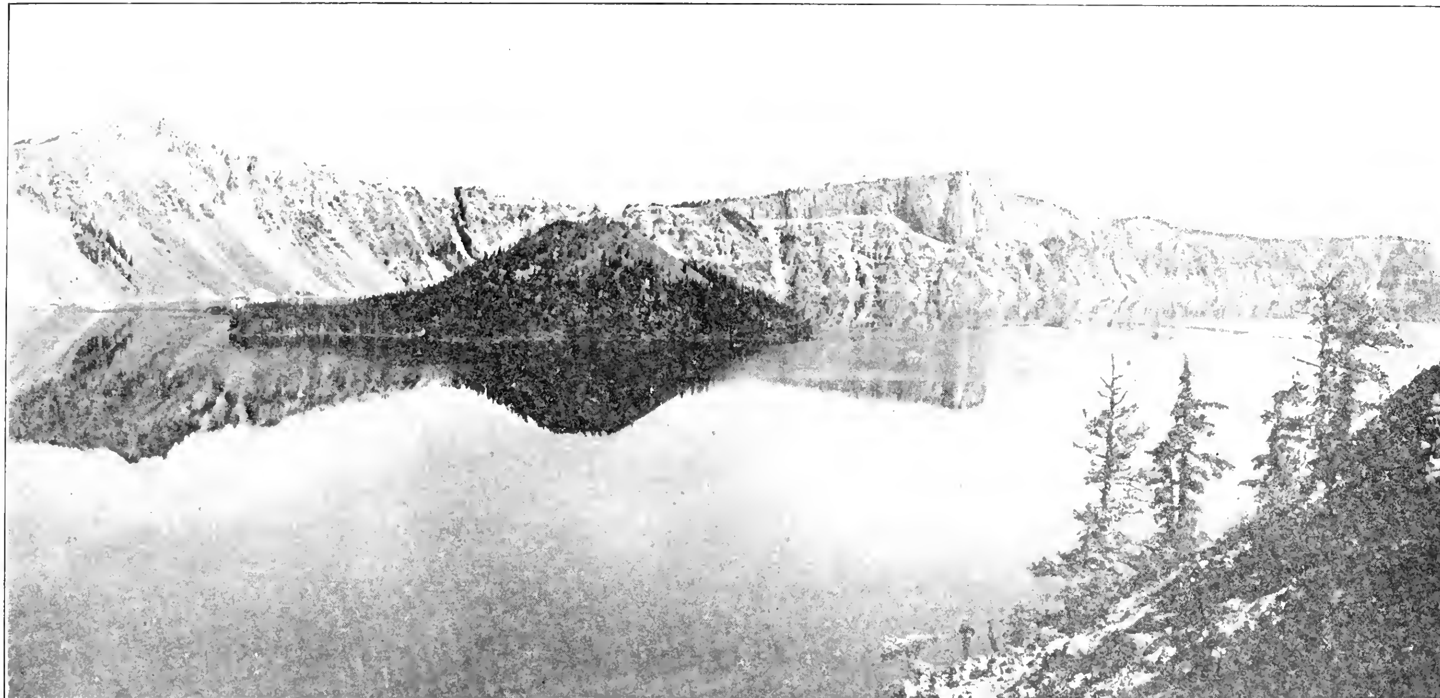
The question might well be asked why such work as this was not undertaken sooner by the government. The principal reason is that every officer of the government directing the affairs of the national parks is burdened with a mass of administrative details relating to other matters. The parks have been placed by law under the direct supervision of the secretary of the interior and the detailed administrative work is all done by officials immediately subordinate to the secretary. The Hot Springs of Arkansas were made a government reservation in 1832 and in 1872 the Yellowstone, the first of the great



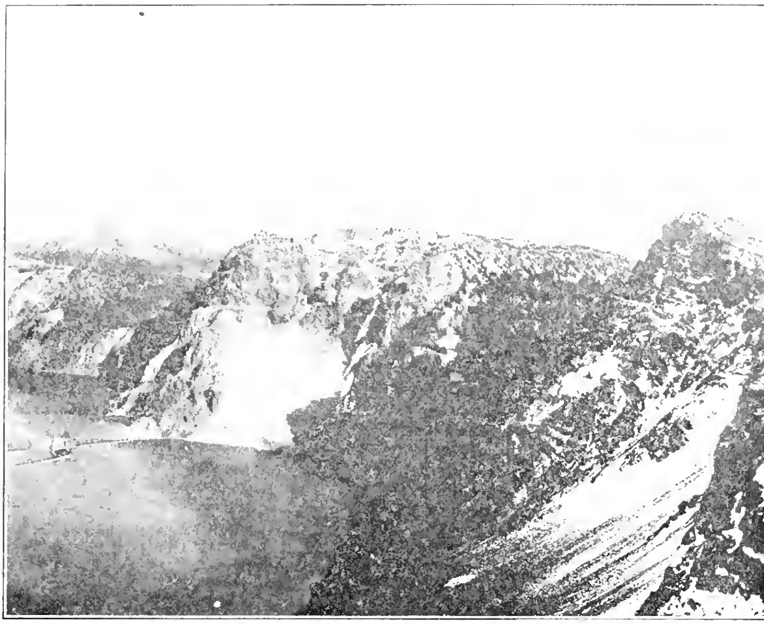
Photograph by H. C. Best.

YOSEMITE FALLS. The upper fall is 1,430 feet; then come cascades, partly hidden, in which the fall is 675 feet, and finally a drop of 320 feet.

national parks, was created. Other parks were created as follows: The Yosemite, Sequoia and General Grant in 1890, the Mount Rainier National Park in 1899, the Crater Lake and Platt national parks in 1902, the Wind Cave National Park in 1903, the Sullys Hill National Park in 1904, the Mesa Verde National Park in 1906 and the Glacier National Park in 1910. Bills are now pending in congress for the creation of the Mammoth Cave National Park in Kentucky, the Peter Lassen, Mount Shasta and Lake Tahoe National Parks in California, the Mount Olympus National Park in Washington, the Saddle Mountain

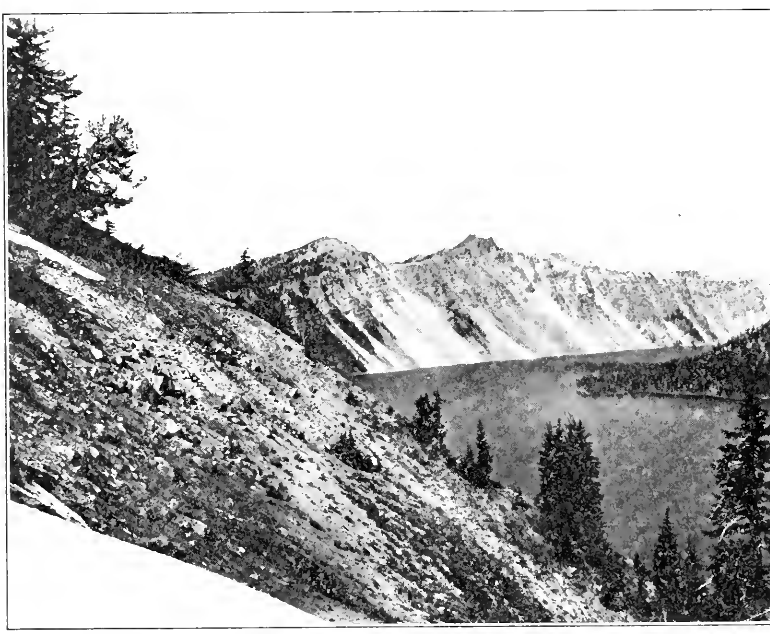


Crater Lake, looking Northwest from Victoria Rock. Crater Lake National Park.
This lake is situated in the crater of an extinct volcano. The upper portion of the mountain has collapsed, leaving the caldera.



Photograph by J. S. Diller.

SOUTHERN SHORE OF CRATER LAKE.
From Castle Crest, Crater. The phantom ship is seen on the left.

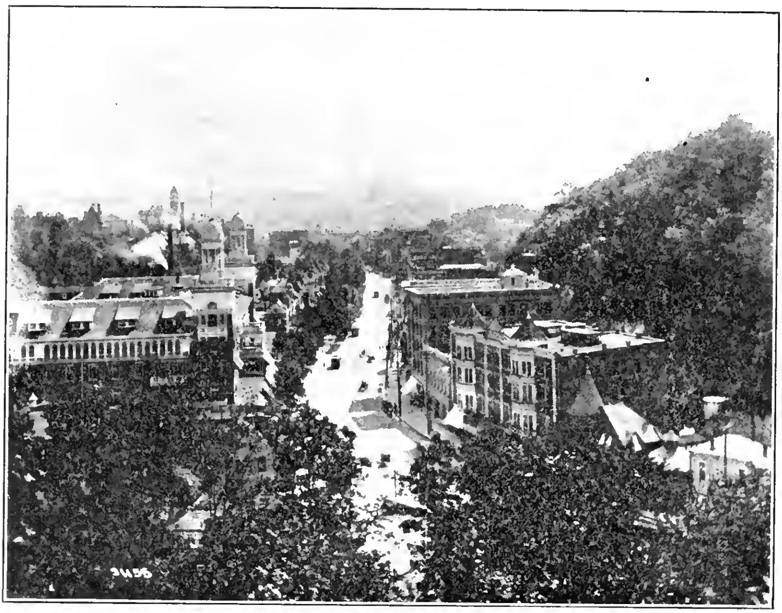


Photograph by J. S. Diller.

WESTERN BORDER OF CRATER LAKE.

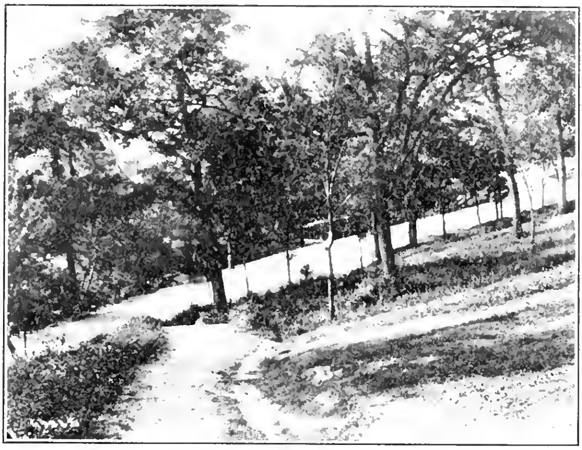
National Park in Oregon and the Rio Grande National Park in New Mexico. A bill was introduced in the last congress providing for the creation of the Grand Canyon National Park. The Grand Canyon now has the status of a national monument in a forest reserve. The creation of the following national parks has been advocated, but no bills have been introduced providing for them: The Kilauea National Park around the volcano of Kilauea in Hawaii and the Estes National Park in Colorado.

The secretary of the interior is also charged with the supervision of seventeen national monuments created by executive proclamation under authority of the act of congress approved June 8, 1906. This act au-



General View of the City of Hot Springs.

thorizes the President "in his discretion, to declare by public proclamation historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest that are situated upon the lands owned or controlled by the government of the United States to be national monuments." The national monuments under the supervision of the secretary of the interior are as follows: the Devils Tower, a landmark in Wyoming; Montezuma Castle, Tumacacori, Chaco Canyon and Gran Quivira in New Mexico, and Navajo in Arizona—prehistoric or Spanish ruins; Muir Woods in California—a beautiful redwood grove presented to the government by William Kent; El Morro in New Mexico—a rock containing inscriptions made by the early Spanish explorers; Pinnacles in California—a group of spire-like for-



Mountain Road, Hot Springs Reservation.

mations underlain by caves; Mukuntuweap in Utah—a peculiar and beautiful gorge; Shoshone Cavern in Wyoming and Lewis and Clark Cavern in Montana—limestone caves of great beauty; Natural Bridges and Rainbow Bridge in Utah—the four largest natural bridges in the world; Sitka in Alaska—the location of one of the earliest settlements and containing some of the finest totem poles known: Colorado in Colorado—an area of eroded monoliths similar to the well-known Garden of the Gods near Colorado Springs; Petrified Forest in Arizona—an area containing large deposits of silicified wood. Ten other national monuments are administered by the Department of Agriculture.

That the parks have been administered so ably and successfully is due to the faithful and devoted work of the officers in charge for many years. By much work beyond the regular office hours these officials have managed to attend to the pressing questions and the current busi-

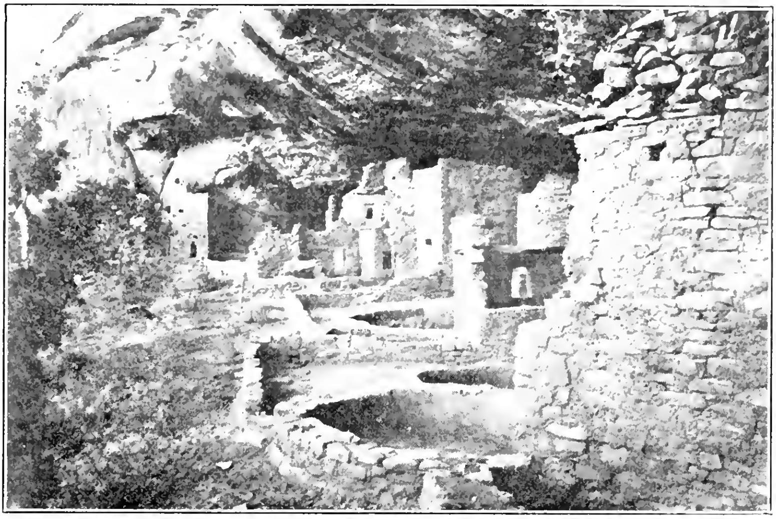
One of the Bath Houses on the Hot Springs Reservation.

Balcony House, North End, Mesa Verde National Park.

ness that have come before them. But there has been neither time nor energy for planning a series of publications such as have been outlined and it has been extremely difficult to make the limited beginning described above. The essential things have been done, but many desirable things have perforce been left undone.

Photograph by Arthur Chapman.

Spruce Tree House, Cliff Dwellings, Mesa Verde National Park, Colo.



Photograph by Arthur Chapman.

CLIFF PALACE, MESA VERDE.

The number of visitors to the national parks has increased from 30,000 in 1906 to 93,000 in 1911. With this increase in the number of visitors the administrative problems have increased, and in order that national park affairs may receive the careful and detailed consideration they deserve, Secretaries Ballinger and Fisher have advocated the creation of a bureau of national parks. President Taft has warmly approved the proposal to create this bureau and in his message of February 2, 1912, referred to it as follows:

> I earnestly recommend the establishment of a bureau of national parks. Such legislation is essential to the proper management of those wondrous manifestations of nature, so startling and so beautiful that every one recognizes the obligations of the government to preserve them for the edification and recreation of the people. The Yellowstone Park, the Yosemite, the Grand Canyon of the Colorado, the Glacier National Park and the Mount Rainier National Park and others furnish appropriate instances. In only one case have we made anything like adequate preparation for the use of a park by the public. That case is the Yellowstone National Park. Every consideration of patriotism and the love of nature and of beauty and of art requires us to expend money enough to bring all these natural wonders within easy reach of our people. The first step in that direction is the establishment of a responsible bureau which shall take upon itself the burden of supervising the parks and of making recommendations as to the best method of improving their accessibility and usefulness.

One of the chief functions of such a bureau should be to arrange a series of publications that will deal clearly and in general terms with the geology, the botany and the zoology of these great reservations that are being administered by the government for the benefit of the people. The educational value of such a series of publications can hardly be estimated.

RESEARCH IN MEDICINE[1]

By Professor RICHARD M. PEARCE
UNIVERSITY OF PENNSYLVANIA

II. The Development of Laboratories for the Medical Sciences

IT would be interesting to trace in the events and activities of the later years of the eighteenth and early years of the nineteenth centuries that development of general thought which exerted indirectly an influence on modern medicine; but, under the circumstances, I can outline only a few; it was the period of the struggle for American Independence, of the French Revolution and of England's abolition of the slave trade. The world was becoming wiser and more humane; men and women were no longer hanged for witchcraft: the principle of education for all was being recognized; and it was also at this time that the insane were treated as persons ill of disease and not as prisoners, to be chained together and crowded into filthy pens until death should end their misery.

Captain Cook was enlarging the boundaries of the known world. Daguerre was establishing the art of photography, Murdoch was developing the use of coal gas as an illuminant. Watts was improving the steam engine, Fulton was concerned with the steamboat and Stephenson somewhat later with the steam locomotive. Machinery was being invented to replace hand labor, and advances in technical and industrial procedures were rapidly following one another.

It was likewise a period marked by the rise of great chemists and physicists, as Lavoisier, Scheele, Priestley, Avogadro, Dalton, Gay-Lussac, Davy, Volta, Franklin and Galvani; great naturalists as Cuvier, Humboldt and Lamarck; and great astronomers and mathematicians as Herschel and Laplace. At the time, the activities of these men were not seen to be directly contributory to the science and practise of medicine, but as the years went on and it became more and more evident—largely as the result of their work—that knowledge was to be gained not by establishing all-embracing systems of philosophy, but by the accumulation of facts through exact observation and experiment, their methods became the property of all branches of science and so, naturally, of medicine. In addition to method, moreover, these men offered, in the fruits of their labors, a not inconsiderable amount of data of

[1] The Hitchcock lectures, delivered at the University of California, January 23–26, 1912.

direct value to medicine, in the establishing of sound principles of physiology.

In the meantime, however, the practise of medicine labored under great difficulties and was largely a matter of empiricism. Without a knowledge of etiology, without pathological anatomy, that firm foundation for diagnosis, and without a rational therapy it could be nothing else. Mercury, cinchona, cathartics and bleeding were the general methods of treatment. Great and noble men filled the universities and hospitals; they labored conscientiously, and elaborated systems, and did what they could to relieve human misery, but to the advance of the science of medicine they contributed little or nothing.

Anatomy as a descriptive science dealing with adult structures and their gross appearance had been well established; but it waited for its fullest development upon the methods destined to establish histology and embryology. Experimental physiology, except as Haller and Hunter had influenced it, was an unknown field, soon, however, to be widely explored as the result of the introduction of instruments of precision and analytical methods. Pathology, dependent upon the methods of histology and physiology was marking time, and, in turn, internal medicine awaited the development of pathological anatomy. Surgery, slowly improving technical procedures, likewise marked time until anesthesia and asepsis opened new worlds to it.

The advance in these general subjects it is my intention to follow along the lines of physics, chemistry and biology, as they developed in France, England and Germany. And, if in the course of this presentation I have much to say about the work shops of these sciences, it is because universities, laboratories and hospitals, as well as societies and journals, represent the visible machinery of nineteenth century research in medicine, and whether we regard them as the cause or the effect of the awakening of 70 years ago, they to-day constitute our hope for the future of medical research.

It is difficult to select a starting point for a systematic survey. Chemistry, however, appears to promise the most direct course, for it was toward the end of the eighteenth century that Lavoisier introduced the modern scientific spirit of exact measurement as applied to chemical phenomena and through it established the great reform responsible for modern chemical knowledge and research. Carbonic acid had already been discovered by Black, hydrogen by Cavendish, nitrogen by Rutherford and ammonia by Priestley; oxygen had been studied by Priestley, Scheele and Lavoisier, so that with Dalton's atomic theory, Cavendish's analysis of the air and Lavoisier's study of oxidation, definite knowledge of the chemistry of air and water, and of combustion and respiration was at hand for the use of the physiologist and physiological chemist. At about the same time the science of crystallography

was established and somewhat later Davy's use of the electric current in the study of the alkaline earths.

In a word, activity in chemistry was evident everywhere, and theory and methods were being rapidly developed, but nowhere was chemistry a part of university study. Berzelius, Gay-Lussac and others had organized laboratories for the training of chemists, but it remained for the University of Giessen to establish the first chemical laboratory under the control of a university. Here, Liebig in 1826, when only 21 years of age, opened his laboratory and began his labors in organic chemistry.

The event is of importance, not only for chemistry, but for medical research in general, for the admission of chemistry to the university was the first step towards the overthrow of the "natur-philosopher" and hence to the development of that modern science which has made German universities so justly famous. It is also important from another point of view; in France science had been the work of the academicians, in England of workers in private laboratories or in those supported by commercial companies; by the new departure at Giessen, the precedent for university laboratories was established, and the world has since followed Germany's lead.

This laboratory of Liebig at Giessen was a success immediately and became the training school for most of the eminent chemists outside of Paris. The training offered at Giessen was systematic and methodical in qualitative, quantitative and organic analysis. In his autobiography, Liebig speaks of the difficulty "as the numbers increased, of the practical teaching itself" but "a progressive way of working" was thought out and tried, I can not refrain from quoting his own words concerning the development of the work in organic chemistry.

> The first years of my residence at Giessen were almost exclusively devoted to the improvement of organic analysis, and with the first successes there began at the small university an activity such as the world had not yet seen. . . . Every one was obliged to find his own way for himself. . . . We worked from dawn to the fall of night, there were no recreations and pleasures at Giessen. The only complaints were those of the attendant, who in the evenings, when he had to clean, could not get the workers to leave the laboratory.

In another place he says:

> I have found among all who frequent this laboratory (Giessen) for technical purposes a prominent inclination to occupy themselves with applied chemistry. They usually follow hesitatingly and with some suspicion my advice to leave alone all this time-absorbing drudgery, and simply to become acquainted with the necessary ways and means of solving purely scientific questions.

Such were the habits, the methods of work and the ideals of the man who in four years established that simple and accurate method of organic analysis known by his name. From his labors and those of Wöhler, who in 1828 announced the first synthesis of an organic sub-

stance (urea) dates our modern organic chemistry. Liebig representing the school of Gay-Lussac and Wöhler that of Berzelius, one at Giessen and the other at Göttingen, serve as an interesting example of scientific cooperation to develop a new science.

Liebig's work led directly to those activities which we now group under the term physiological or biological chemistry, but physiology was at this time making rapid strides along another line of attack—the application of the principles of mechanics and physics. The part of physics in medicine from Galileo to Roentgen is one of the most fascinating phases of the history of medicine; in principle and practise, in theory and science, its influence has been one of fundamental importance and in its application to methods of clinical diagnosis it shares equally with pathological anatomy in the awakening of modern clinical medicine. The first widely reaching application was in Harvey's interpretation of the circulation of the blood and the action of the heart, but it was not until organized physiological laboratories had been instituted that the application of the principle of physics bore abundant fruit. To recall the state of physics at that time it is only necessary to state that the work of Galvani and Volta was completed and that Ampère and Ohm, Faraday and Wheatstone, were still active. Charles Bell had already (1811) given to England the second of two great discoveries in physiology, the differentiation of sensory and motor nerves. Haller, as we have seen, had in the preceding century presented and discussed the irritability of muscle. The time was at hand for the study of the general physics of muscle and nerve and the special senses. Ernst Weber announced the principles of his psycho-physics in 1825 and Johannes Müller those of his physical chemistry in 1826; Purkinjé had already established the first university laboratory of physiology in 1824 at Breslau; in 1838 the celebrated physiological institute at Berlin was formed under the direction of Müller and in 1840 Ernst Weber was made professor of physiology at Leipzig. From these two centers, Berlin and Leipzig, from Johannes Müller and Ernst H. Weber, came a great volume of minute investigations based on exact methods of inquiry. Both schools were largely busied with studies of the mechanism of the perceptions of the senses, that of Weber tending to include mental phenomena, thus anticipating the modern school of psychologists, that of Müller including not only the methods of physics, but also those of general biology. Müller (1801–1858) was indeed the last of a school which attempted to embrace all of the territory of biology in its broad sense; a territory which now has its separate and distinct fields of morphology, physiology and chemistry. He may, however, be regarded as responsible for some of the divisions into which the older biology has been split, and for the impulse to new lines of study, for he was the teacher of the masters who came in time to occupy high places in biol-

ogy, of Schwann and Henle in anatomy, of Du Bois-Reymond and Helmholtz in physiology and of Virchow in pathological anatomy. It is not surprising therefore that it was the proud boast of this school that not only had it dispelled the vague notions of the old metaphysical school and established in its stead the true scientific spirit, but that it had filled so many of the chairs of medicine, physiology and anatomy in the German universities that the scientific spirit has been applied to "every branch of medical science, which it has in consequence drawn into the circle of the exact or mechanical sciences." (Merz.)

This is not the place to go into detail concerning the investigations of Müller and his school of physiology. His *law of "specific energies,"* Du Bois Reymond's electro-physiology and Helmholtz's work on musical acoustics and physiological optics indicate the character and scope of the work. The keynote of it all Müller himself has expressed in his "Elements of Physiology" as follows:

> Though there appears to be something in the phenomena of living beings which can not be explained by ordinary mechanical, physical or chemical laws, much may be explained, and we may without fear push these explanations as far as we can, so long as we keep to the solid ground of observation and experiment.

These principles and the labors of this school were advanced wonderfully, in 1847, by Ludwig's invention of the kymograph and the elaboration of methods of graphic registration, factors which established this phase of physiology on a sound basis and exerted an influence which medicine feels to this day. This, however, was not the only influence of Müller. As a biologist with general interests he stimulated general biological research and it was undoubtedly this influence exerted through Schwann that led the latter to grasp the importance of Schleiden's work on vegetable cells and to apply the observations of the latter to the cells of the animal body.

But although the cell doctrine, in its modern conception, is the result of the work of these two men, Schleiden and Schwann, it is not to be supposed that they were the first to study cells, for before Schleiden considerable attention had been given to the structure of vegetable tissues. Robert Hooke in 1665 had given to the spaces in cork and similar structure the names of "cells"; Malpighi (1674) and Grew (1683) had, as far as their low power lenses would allow, described plant tissue as made up in part of cell-like cavities provided with firm walls and filled with fluid, and in part of long tube-like vessels. Treviranus, in 1806, demonstrated that these tubes arose as the result of cells becoming attached end to end, the intervening ends eventually disappearing. The nucleus of the cell had been discovered in 1831 by Brown, who, however, failed to realize its importance. Not so Schleiden. He attached great importance to the nucleus and by the numerous observa-

tions (1839–1843) which he brought forward was able to formulate a definite cell theory for plants; later when this theory was applied to animal tissues and developed by Schwann and Virchow it became an influence as great as that of the theory of evolution, in the development of modern biology.

Schwann, who was at the time an assistant of Müller, received directly from Schleiden the impulse to compare animal and vegetable cells. While carrying out for Müller the experimental study of nerve and muscle, necessary for the proper preparation of his chief's great book on physiology, he became interested in the histological study of these structures and it was at this time that he described the nerve fiber sheath which now bears his name. Once, when he was dining with Schleiden in 1837, the conversation turned to the nuclei of vegetable cells, Schleiden's description of these recalled to Schwann similar structures which he had seen in animal tissues. The resemblance between the animal and plant cells was, without loss of time, confirmed by both observers and the result was Schwann's famous paper (1839) on the accordance in structure of animal and plant tissues.

It is difficult for the student of to-day, thoroughly drilled concerning the details of cell structure in his courses in normal and pathological histology, to realize that only a little over 70 years ago the essential feature of the animal cell, the nucleus, was not recognized, and that it was a botanist who first brought the subject to the attention of a physiologist. Medicine in all its phases has advanced rapidly along the path thus opened up by Schleiden and Schwann. To-day we are interested above all other things in the chemistry of the cell, but from the time of Schwann to the time of Pasteur the study of the morphology of the cell in health and in disease was one of the chief interests of scientific medicine.

It is not to be supposed, however, that Schwann had the conception of the cell which we have to-day. He, as Schleiden before him, made faulty observations and drew faulty conclusions. The important features of Schwann's work were the recognition of the nucleus, not the cell wall, as the important part of the cell, the demonstration of the union or grouping of the cells to form tissues,[2] and the demonstration that the distinctive cells of the tissues of the adult develop from the undifferentiated cells of the early embryo. The misconceptions of the early histologists were natural when we recall the great technical diffi-

[2] This statement does not disregard the work of Bichat (1771–1802), frequently called the "father of histology," to whom is due the credit of first recognizing the fact that the body was made up of distinct and differing tissues. Bichat's results, however, were obtained by the use of chemical reagents. He used the microscope but little, and his work, important as it was, and antedating the cell theory by 40 years, can not be considered as leading to the development of the cell theory.

culties with which they had to contend. The microtome, the microscope, and differential staining methods, in their present-day perfection did not exist for them. It was the day of the razor and hand sectioning. The first microtome appears to have been that used by Professor His in 1866; the improvements leading to the perfection of the present-day microtome did not begin until 1875. The development of the objective of the compound microscope was just beginning in Schwann's time (1830). Although iodine was early used, it was not until about 1857 that Geleach called attention to carmine, the first nuclear stain to be introduced into histological technic. At first, tissues were examined only in the fresh state and even later when hardened they were not imbedded as now in celloidin or paraffin, but placed between vegetable pith or blocks of amyloid organs during the process of cutting.

Surely the technical difficulties were great and we are not surprised that both Schleiden and Schwann believed new cells to be formed through a process of "crystallization" from a "mother liquor" or cytoblastema and that the cell was a vesicle with a solid wall. This question of minute structure and that of mitosis yielded eventually to improvements in technique and Schleiden's theory of the formation of cells *de novo* was discarded, and we know from Virchow's famous aphorism "*omnis cellula e cellula*" that in his time it was established that cells arose only by the division of preexisting cells. This general law was the result largely of the work of botanists, as Hugo von Mohl and Nägeli, and was applied by Virchow (1858) to animal tissues only after much work had been done on such tissues by Kölliker, Reichert and Remak. It was not until 1873 (Anton Schneider) that an insight into the details of cell division was gained and it was 1882 when the part of the nucleus in karyokinesis was satisfactorily demonstrated and Flemming could supplement Virchow's aphorism with another "*omnis nucleus e nucleo.*"

Thus did Schleiden, a botanist of the University of Jena, and Schwann, assistant (1824–1838) to Müller, establish one of the most brilliant and most important generalizations of the century, which became at once the basis of all morphological studies, and, as applied by Virchow, placed pathology on a scientific basis, and has continued as a result of its general biological applications—to development, inheritance and immunity—to influence medicine profoundly. As Verworn has said:

> It is to the cell that the study of every bodily function sooner or later drives us. In the muscle lies the problem of the heart beat and that of muscular contraction; in the gland cell resides the cause of secretion; in the epithelial cell, in the white blood corpuscle, lies the problem of the absorption of the food, and the secrets of the mind are hidden in the ganglion cell.

It will be necessary to return to the cell theory again in discussing

the development of pathology, but we may leave it for the moment to trace one other line of advance made by the physiologist; an advance in that phase of the subject which Du Bois Reymond characterized, in 1880, as "vivisection and zoochemistry" in contrast to the electro-physiology of nerve and muscle with which his own name is so closely linked, and in contrast also to the phase of physiology in which histology, following the lead of Schwann, was playing so large a part. This third field in physiology necessitates a shift of scene to France and Claude Bernard and his school and the study of the functions of organs and their secretions.

Claude Bernard (1813–1878) was the pupil and successor of Magendie. Magendie did many things, but best of all he made "the experimental method the corner stone of normal and pathological physiology and pharmacology." (Welch.) By this method he demonstrated, as Charles Bell had divined, the essentially different functions of the anterior and posterior roots of spinal nerves. Also he founded a journal of experimental physiology.

Bernard, departing widely from Magendie's work, followed in his researches one main idea, the action of the nervous system on the chemical changes which constitute the basis of nutrition and this problem he attempted to solve by either direct experimental investigation of nerves, or by chemical researches or by a combination of both methods. His most important discoveries were the demonstration (1) of the significance of the pancreatic juice in digestion; (2) the glycogenic function of the liver and (3) the vasomotor system. These investigations (1850–1860) with those of Ludwig (1851) on the mechanism of the secretion of the glands, with the earlier observation on gastric digestion made by our own countryman, William Beaumont (1833), and the discovery of pepsin by Schwann (1835) represent the principles out of which our present conception of the physiology of digestion has developed. Not only did Bernard make discoveries and work out the lines of progress for the study of the outward or external secretions of glands, but as a result of his study of the influence of the liver on carbohydrate metabolism, he formulated the theory of "internal secretions," which represents a field of physiology cultivated in the past few years with the greatest success and still full of promise for the future.

Bernard has the distinction of being the first man of science to whom France accorded a public funeral, a recognition not alone of personal worth, but also of the nation's debt to science and to research in the field of medicine.

Thus far I have presented the beginnings of those branches of medicine which deal with normal structure and function. Next in order of development comes that science which is concerned with the study of disease, pathology and upon which are based sound diagnosis and

rational therapy and for this reason the science of most interest in medicine. Pathology owes its position as a recognized science to the genius of Virchow, but, in its development, it also owes much to the period I have just discussed, as I will show in due time. To present this development properly it is necessary to turn back to 1761 and Morgagni. I must again remind you that in Morgagni's time medical science can hardly be said to have existed. It was the period of a vague philosophy which attempted to systematize diseases according to symptoms, with no reference to the anatomical conditions causing the symptoms. It was Morgagni who first insisted that the clinical history should be set side by side with the results of the autopsy and who by his publication "De Sedibus et Causis Morborum" threw the first gleam of light on the causes and nature of diseased processes, and thus gave a stimulus to the study of pathological anatomy. Before Morgagni's time, and for some time after, pathological anatomy was mainly concerned with the recording of the rare and curious, with malformations and obvious departures from the normal type; observations oftentimes interesting, but not systematized or harmonized. Morgagni is responsible for the maxim that observations should be "weighed not counted," and it was undoubtedly this point of view which influenced his observations and led eventually to the doctrine that most diseases were to be explained by changes in the organs of the body.

Another step in advance was taken when Bichat, about a quarter of a century later, referred disease to the tissues of the organs. In the meantime John Hunter (1728–1793) had applied to the problems of clinical medicine methods which we now recognize as those of experimental pathology. Still pathology was not a science; it was not systematized and it had no underlying principle. The systematization of pathological anatomy came through Rokitansky[3] (1804–1878) and the underlying principle of pathology from Virchow in 1858.

Rokitansky, the father of pathological anatomy, was an assistant to Johann Wagner, later succeeding him in 1834 as prosector and finally in 1844 as professor of pathological anatomy at Vienna. Wagner had encouraged the application to pathology of the methods of anatomy, and the publication of Rokitansky's "Handbuch der pathologischen Anatomie," completed in 1846 (one year before Virchow's "Archiv" was founded), presented to the profession the results of a most thorough study of the details of pathological anatomy. It is said that Rokitansky performed, as the basis for his classifications, more than thirty thousand autopsies. His position in pathology has been likened to that of Linnæus in botany. "Even to-day nothing can equal the accuracy of Rokitansky's observations. There are few things he did not see. When some lesion or combination of lesions seems entirely

[3] A worthy predecessor of Rokitansky was Johann Fr. Meckel, whose "Handbuch d. patholog. Anatomie" was published at Halle in 1804, the year of Rokitansky's birth.

new, it is often only necessary to go back to the work of Rokitansky to find that he had observed and accurately described it." (Councilman.) Although he encouraged the development of pathological histology, pathological chemistry and experimental pathology, he took no active part in these subdivisions of pathology and used the microscope but little. He seems to have been content with the establishment of pathological anatomy as a descriptive science.

Between Rokitansky's work and Virchow's cell theory there is no obvious connection. Between Morgagni, Bichat and Virchow we have an interesting link, that formed by the successive theories which placed disease in the organs, the tissues and the cell, respectively. Rokitansky worked with the organs and tissue and had no influence in carrying the quest on to the cell. The influences which led Virchow to the latter are wholly those we have discussed in the story of physiology and its beginnings, the personal influence of Johannes Müller, Schwann's writings and the results of the application to medicine of the methods of physics and chemistry. That he appreciated the importance of the relations of pathology, on the one hand, to physiology, and on the other to clinical medicine is shown in the title of his Archives established in 1847. It is not surprising, therefore, that he was not satisfied with the pathology as merely the descriptive and classifying science of Rokitansky and that he was the first to recognize that pathology was the study of life under abnormal circumstances, and that chemistry, physiology and embryology had a direct bearing on pathology and that the methods of all the other natural sciences should be applied to the elucidation of the problems of pathology and thus to those of medicine.

Virchow's "cellular pathology," as announced in its final form in 1858, must be considered as a general biological principle as important in the field of its application as Darwin's "Origin of Species" published one year later.

It is said that Virchow first began the observations which culminated in his doctrine of cellular pathology in his student days, while serving as an assistant in the eye clinic of the Berlin Hospital. Here he became interested in the fact that in keratitis and wounds of the cornea healing took place without the appearance of plastic exudate. This led to an investigation which indicated the occurrence of repair by the multiplication of preexisting cells. These studies led eventually to his theory, which Lord Lister has described as the "true and fertile doctrine that every morbid structure consists of cells which have been derived from preexisting cells as a progeny." In this theory he brought pathological processes into relation with normal growth, hence his axiom "omnis cellula e cellula." This was the underlying principle, which, following Rokitansky's work in classification, gave pathology a place among the biological sciences. With his cell doctrine as a guide he made many important contributions to histology both normal and

pathological, and outlined a classification of new growths which is the basis of all present-day knowledge of tumors.

With his activities as anthropologist-archeologist we are not especially concerned except as they indicate the wide range of his interests. He was one of the founders of the German Anthropological Society, and later its president, and made expeditions with Schliemann to Troy, Egypt, Nubia and the Peloponnese.

Of vast importance to medicine, however, was his establishment of the first pathological laboratory, at the time he returned (in 1855) to Berlin from Würzburg after a political exile of eight years; an exile due to his sympathy with the revolutionary tendencies of 1848. This laboratory was the forerunner of the many which have been founded in the past fifty-five years in all parts of the world, and which have been found essential not only for the purpose of teaching and research, but also in the modern hospital. And again of importance is that influence exerted through his famous pupils such as Leyden, v. Recklinghausen, Cohnheim, Waldeyer, Kühne and Rindfleisch, to mention only the more prominent, who carried his views to other fields and continued his methods. Other great influences were to extend the territory of pathology, as, for examples, Cohnheim's conception of experimental pathology, Weigert's tinctorial methods for the differentiation of cells and tissues, Ehrlich's application of these methods to the study of the blood, Metchnikoff's studies in comparative pathology, and finally the science of bacteriology; but with Virchow remains the credit of having established pathology as a science of university rank.

The third of a century beginning in 1828 with the founding of Liebig's laboratory and ending in 1858 with the publication of Virchow's doctrine of cellular pathology, represents a greater advance in the science of medicine than the combined activities of all the preceding centuries. What was the influence of these advances on the art and practise of medicine? Medicine at the beginning of the century was still influenced by the metaphysical treatment of scientific subjects. The previous century had been one of schools and systems, those of Cullen and Brown in England, Broussais in France and Hoffman and Stahl in Germany. It was also the time of Hahnemann (1753–1844) and the rise of homeopathy. The prevailing tendency was to base disease on the study of symptoms, without regard to the underlying pathological changes causing the symptoms. A few quotations may bring this period of change from the old to the new prominently before you.

Helmholtz writes of the period of his student life:

> My education fell within a period of the development of modern medicine when among thinking and conscientious minds there reigned perfect despair. It was not difficult to understand that the older and mostly theorizing methods of treating medical subjects had become absolutely useless. . . . We can not wonder if many honest, serious thinking men turned away in dissatisfaction from medicine, or if they from principle embraced an extreme empiricism.

And again he says:

> At that time there were many among the younger doctors who, in despair about their science, gave up all therapeutics, and took to empiricism.

This was from a scientific man, who had much to do with the changes about to come, and perhaps somewhat biased; but we have the view of Stieglitz, an "old and learned practitioner," expressed in 1840:

> German medicine was sunk so low and is so emasculated as to require any sort of shaking up. Whatever gives it a new direction will be wholesome, though new errors or possibilities may result therefrom.

But, to continue Helmholtz's remarks:

> The right kind of work brought forth its fruits much sooner than many had hoped. The introduction of mechanical notions into the theories of circulation and respiration, a better insight into the phenomena of heat, the more minutely elaborated physiology of the nerves, speedily produced practical results of the greatest importance; the microscopical examination of parasitic tissues, the stupendous development of pathological anatomy, led irresistibly from nebulous theories to real facts.

As Helmholtz was born in 1821 his point of view is that of one who saw both the old and the new; the old in his student days, the new as one of those who labored to bring about the change. His view is largely that of the scientist, but we have fortunately the reminiscences of another, a practitioner of medicine, who labored as a student of medicine in those days of rapid change. I refer to Abraham Jacobi, our own Jacobi, "the father of pediatrics," who studied, as he tells us in his McGill address, "in three universities from 1847 to 1851, in Griefswald, Göttingen and Bonn." Referring to this period, he says:

> I have lived under the eyes of and contemporaneously with great men and during the development of modern medicine . . . not as a cooperator, it is true, but as an interested looker-on, when great things happened.

Aside from Vienna, where Rokitansky taught, there were

> only two places in all Germany in which pathological anatomy could be learned. One of them was Würzburg, there was Virchow, the other was Göttingen, there was Frerichs. So to Göttingen I went in search of pathological anatomy. . . . At the same time I looked for the advantages of chemical laboratory work under Wiggers and Wöhler.

Among the scientific happenings of Jacobi's first medical year (1847) are the following: Helmholtz's address on the conservation of energy; the use of ether anesthesia in obstetric practise by Hamner and in dentistry by Delabarre (first used by Warren at Boston in 1846); Liebig's researches on meats; the employment of prismatic glasses by Kreke and Donders; the first use of chloroform by Simpson; the employment of Duchenne of faradization in the treatment of paralysis; the discovery of unstriped muscle fibers by Kölliker and the studies by Semmelweis of the etiology of fever in puerperal women.

Among the events of the next five years, during three of which he was a student and two a political prisoner, Jacobi mentions: Bunsen's quantitative analysis of urea, the founding of spectral analysis, the use

of cold for anesthesia, Claude Bernard's puncture of the fourth ventricle and his demonstration of the glycogenic function of the liver and of the vasomotor nerves; the discovery of *Trichophyton tonsurans* and *Balantidium coli* by Malmsten, the invention of the spirometer by Hutchinson and of the ophthalmoscope by Helmholtz, and the sphygmograph by Vierordt. Altogether Jacobi tells of a host of observations made in a short period of six years. And the list is not one of laboratory discoveries only. It includes important advances in clinical medicine and surgery, as Meigs's discovery of the importance of thrombosis as a cause of death in puerperal women, Marion Sims's vesico-vaginal operation, Detmold's operation for abscesses of the cranial cavity, Walker's work on the infectious nature of secondary syphilis, Romberg's studies of tabes dorsalis, Pravaz's invention of subcutaneous injection, Kuchenmeister's discovery of the connection between tænia and the scolex found in pork, Bigelow's resection of the femur and Bennet's work on leucocythemia.

More could be quoted from Jacobi's impression of this period, but this is enough to show that medicine was advancing not only in the laboratory, but in the clinic. One may, as Jacobi says, "recognize in my fragmentary enumeration, facts of crucial import."

These advances in clinical medicine and surgery were due to several factors; to the increasing use of the methods of physics, chemistry and biology, to the influence of pathology, to the introduction of new procedures in diagnosis, and in surgery, to the facility of operation offered by anesthesia. What a change in the practise of medicine these observations and applications brought about! How different their influence from that of the earlier schools and systems with which we associate the names of Brown, Cullen, Broussais, Hoffman and Stahl!

Such schools and systems, while of interest to the general historian of medicine, offer no assistance to one seeking the lines of advance dependent on investigation or research in medicine. Fortunately for the history of clinical medicine the systematists did not occupy the field to the exclusion of those guided by objective observation, for we find Sydenham (1624–1689) and Boerhaeve (1668–1738) studying disease unbiased by schools or systems, and applying the methods of close observation which we now recognize as those of modern clinical medicine. But although Sydenham and Boerhaeve and their followers aided progress by the addition of some positive knowledge to clinical medicine, their influence on the development of medicine was not great, for they were before the days of Morgagni, Haller, Hunter, Bichat and Rokitansky and the methods associated with these names.[4] Without patho-

[4] Before and about the time of the period so represented, some of the important contributions made to clinical medicine and pathological anatomy were as follows: aneurism and diseases of the heart by Lancisi, Albertini and Senac; an investigation by Fothergill, of the diseases now known as diphtheria and tic

logical anatomy clinical classification was impossible, and without physiology and the methods of the physiologist, clinical interpretation was difficult. The influence of pathological anatomy on clinical medicine was felt first in England through Baillie (1761–1823), a pupil of Hunter; in France, after Bichat, through Louis, Andral and Lænnec; in Germany through Schönlein and Romberg; and in America through the pupils of Louis. The discovery of the diseased conditions with which we associate the names of Bright, Pott, Addison, Graves, Stokes and Hodgkins came at this time, as also Marshall Hall's discrimination of diseases of the spinal cord and Bayle's study of tuberculosis of the lung. It was the period when the best members of the profession endeavored to give to the study of symptoms the same precision as characterized anatomical observation and to combine the results of this method with the revelations of pathological anatomy. It was this method that culminated in Louis's so-called "numerical or statistical method," the method of basing conclusions on large groups of records rather than on isolated observations, and which, in this country, through the work of two of Louis's students, Gerhard and Stillé, led to the differentiation of typhoid fever from typhus fever, with which it had been confounded.

But of equal importance was the second influence which was at work, that of improved methods of diagnosis of diseases of the heart and lungs, the methods of percussion and auscultation. Percussion was first used by Auenbrugger, in 1761, but was treated with contempt and ridicule until 1808 when his pamphlet was translated into French by Corvisart, who proclaimed the value of the method and obtained for it universal recognition. Shortly after, in 1819, came Lænnec's work on the use of the stethoscope in auscultation, and Skoda in 1839 did much to extend the use of both percussion and auscultation.

This phase of medicine, the development of instruments and means of studying diseases of the internal organs and the organs of the special senses—the history of the stethoscope, the ophthalmoscope, the laryngoscope, and like instruments—is a most fascinating subject and one worthy of extended treatment, but it must suffice here to state that the new methods of direct exploration brought about a complete revolution in the knowledge of disease and had "more influence on the development of modern medicine than all the 'systems' evolved by the most brilliant intellects of the eighteenth century." (Payne.)

Exact clinical observation, the study of pathological anatomy and the increasing use of instruments and methods tending to accuracy in diagnosis were, therefore, the characteristic features of the early nineteenth century school of medicine. Both medicine and surgery were

douloureux; of prison and camp fevers by Pringle, of epidemic fevers by Huxham; of diseases of the skin by Willan, of angina pectoris by Heberden, and of gastric ulcer by Baillie.

developing along lines which ensured accelerated progress under the impetus of the discoveries in bacteriology which were soon to follow, and we could with propriety pass on to the era of bacteriology, if it were not for one great boon, destined to have an enormous influence on the practise of surgery, on the diminution of human suffering and on the general advance of research in medicine. This was the introduction of anesthesia. Surgery had steadily advanced in technic, resourcefulness and daring, but the torments of surgery were such that operations were mainly those of necessity. As Mumford says:

> Surgical pain was real enough; there was no disguising it. The terror of operation was a very hell, even in anticipation; the fact itself no man has found words to describe. The shadow of it has lengthened even to our own day. Surgeons as well as patients dreaded the knife.

Robert Liston, two years before the discovery of ether congratulated his students that the "field of operative surgery" was "happily narrowed." Keen writes:

> It is a striking commentary on the immediate results of anesthesia to learn that, in the five years before the introduction of ether, only 184 persons were willing to submit themselves to such a dreadful ordeal in the Massachusetts Hospital, an average of 37 operations per annum, or 3 per month. In the five years immediately succeeding its introduction, although the old horror could not be overcome, 487 operations, or almost 100 annually, were performed in the same hospital. During the last year (1898) in the same hospital 3,700 operations were performed.

This change was brought about in 1846, when W. T. G. Morton, an American dentist, by publicly administering ether, proved to the world that it was a safe and sure anesthetic. The operation was performed by John Collins Warren at the Massachusetts General Hospital and the names *anesthesia* and *anesthetic* were suggested by Oliver Wendell Holmes. Anesthesia was therefore essentially a Boston affair as far as its introduction to the world was concerned, but the claims of its discovery made by others (Long, Jackson, Wells, Marcy) leave the question of priority in the knowledge of and use of ether in much confusion. With this phase we are not at present concerned. One year after the demonstration in Boston, Simpson, of Edinburgh, recommended chloroform as an anesthetic of equal value with ether. Not only surgery but obstetrics, dentistry and the various specialties benefited by this great boon of anesthesia and within a year the administration of anesthetics was a universal practise throughout the civilized world. Surgery, freed of its horrors, developed along lines hitherto undreamed of, and made those rapid strides which prepared it for the era of antisepsis in the next generation.

The next lecture will concern itself with the story of Pasteur and the development of bacteriology and the influence of the latter on medicine and surgery.

AGE, DEATH AND CONJUGATION IN THE LIGHT OF WORK ON LOWER ORGANISMS[1]

By Professor H. S. JENNINGS
THE JOHNS HOPKINS UNIVERSITY

UNFORTUNATELY we are all interested in the subject of age and death. But the interest is of the kind that my friend Professor Lovejoy calls the interest of the repulsive. If we were free in the matter, we should doubtless prefer to neither hear nor know anything about the subject. But since to continue in that state of blissful ignorance and inexperience is impossible, we are driven to ask certain questions on the matter. What is the reason for our weakening and disappearing, along with all the visible living things that surround us? Why might we not as well continue indefinitely our interesting careers, instead of dropping off just as we become able to do something worth while? And *must* it be so inevitably? Is it grounded in the nature of life that all that live must die?

From the ancient seekers after the fountain of youth to the modern physiologists working toward the preservation of life, the prolongation of its processes, and the suppression of death, there have not lacked men who cherished the bold thought that death may be no essential part of life, that possibly some means may be found for counteracting the process of aging, for excluding death. And these men but express a secret wish of all mankind.

In this condition of affairs, a field of great interest was opened when the microscope revealed to us a world of organisms which seem at first view not to get old and die. As we follow them from generation to generation, the infusorian, the bacterium, seem not subject to the law of mortality. These creatures live for a time, then divide into two, and continue to live. Death appears, as we watch them, to occupy no place in their life history, save in consequence of accident.

This seemed to settle one of the great questions: whether age and death are inherent in life; inseparable from it. Here apparently was life without death; here was perpetual youth. If this can be in the infusorian, why not in other organisms, why not in man? Or if our thoughts be not so bold as this, may we not by study of the infusorian at least satisfy to a certain degree our understanding, learn perhaps something of the origin, cause and nature of age and death, and of the nature of that kind of life which avoids it? It is because I have de-

[1] A lecture before the Harvey Society of New York, March 3, 1912.

voted some years to a study of these matters in such creatures that I venture to speak to you on this subject.

You remember that one of the famous early essays of Weismann was upon the question I have just raised. He tried to show that death is not at all necessarily involved in living; that natural death originally did not exist, and does not exist now in these lower creatures; with theology he held that death was acquired in the course of time, and the Satan that "brought death into the world and all our woe" was no other than natural selection, acting for the benefit of the race, as distinguished from that of the individual. The body in the course of time becomes worn, battered, crippled. It is well to have at intervals a clearing out of this worn stock; new, fresh bodies replace the battered ones and a race which undergoes regularly this renewal must prevail and perpetuate itself in the place of those that do not; such is the conception of Weismann. Thus, too, the sum of happiness in the world is kept at the highest mark, since the fresh and perfect can enjoy much more than the worn and crippled.

But according to this view, if organisms could but live in such a way as to keep the body fresh and uninjured, there would be no need for death. And the organisms which have succeeded in doing this are the infusoria and their relatives. These, in the famous phrase of Weismann, are "potentially immortal."

But another fact in the lives of these creatures attracts strongly the attention of the observer. These same unicellular organisms that appear to live forever do likewise go through the same process of sexual union that we find in higher animals. Now this sexual union has proverbially stood as the token of mortality; it is the preparation for the new generation, and prefigures the disappearance of the old one. You will recall the famous remark of Alexander the Great upon this point.

Why then should this take place in these ever-living creatures? The fact that it does was held by many to indicate that to consider these creatures ever-living was a mistake; they predicted that these animals would be found not potentially immortal, but subject to death at the end of a certain term, just as are higher animals. It is interesting to discover here, as in so many other cases, that the diverse possible opinions on the subject were formulated and maintained before investigation had obtained evidence as to the facts in the case.

But men were not content to speculate: and Maupas in one of the great investigations of biology (1883 to 1888) undertook to determine the truth of the matter. We must look briefly at the questions which were raised, and the answers that were obtained by Maupas and by others, for it will help us to understand the present state of the matter.

Maupas took a single individual (a *Stylonychia*), kept it with plenty of food, and allowed it to multiply by repeated division into two;

he followed thus its history from generation to generation. The creatures divided every eighteen hours or so, and for about a hundred generations they remained strong and healthy. Then sickly and deformed individuals began to appear here and there; these became more and more numerous, till finally all had degenerated thus; they died out completely at the end of five months, after 215 generations. Another series, beginning with an animal that had just conjugated, degenerated and died at the end of 316 generations; and other series gave similar results.

Thus, said Maupas, it is clear that these creatures do get old and die, just as higher animals do. The idea that they are potentially immortal is a mistake; death inheres in the process of life.

But why then are not these creatures all dead? How is it that they exist at the present time?

The key to this is found, according to Maupas, and according to the suggestions of many before him, in the process of sexual union. As fertilization saves the life of the egg and permits it to continue dividing for many generations, so does conjugation put new life into the dying infusorian, permitting it also to continue multiplication for many generations. The existence of sexual union in these creatures finds its explanation in the fact that they, like ourselves, are mortal; and their mortality is overcome, like our own, by the process of sexual reproduction. Their lives begin with the strength of youth, and inevitably run down the incline of age, as do our own.

But Maupas was one of those men who are not satisfied with a brilliant hypothesis; if conjugation actually restores vitality, he wanted to see it done. He allowed one of his *Stylonichias* in the 156th generation to conjugate with another that he captured wild. Then he took one from this pair and allowed it to multiply. Most unfortunately he does not say (doubtless he did not know) whether it was the old one or the fresh one that he allowed to continue. But this creature, which had just conjugated, propagated itself for 316 generations before it finally died of old age. Meanwhile, the rest of the old stock, which had not been allowed to conjugate with fresh individuals, died out in 59 generations.

Thus it appeared to be demonstrated that conjugation restores vitality, that it rejuvenates. The brilliant hypothesis had seemingly become the demonstrated reality.

But it is interesting to the student of the history of science, and of scientific certainty, to discover that many years before the time of Maupas the function and effect of conjugation had been completely worked out in detail, by the most painstaking investigations, so that in 1862 a statement for it could be made that, according to the competent judgment of Engelmann, had been by a great abundance of observa-

tions raised above all doubt.[2] Yet this statement, though it seemed to rest on irrefragable evidence, and agreed with everything else that was known, was quite false, and in Maupas's time had been completely abandoned. Perhaps this was a type of the fate to be met by many other supposed demonstrations as to the function of conjugation, including that of Maupas—and not impossibly the one here presented.

Before leaving the work of Maupas, we must mention certain other observations that he made which are of great importance for understanding the matter. In his experiments, after degeneration had begun, many specimens within the same series (all derived from the same parent) conjugated together. But this did not rejuvenate them. On the contrary they died all the sooner after conjugating with close relatives. This happened in many cases.

So Maupas concluded (1) that conjugation with close relatives does not rejuvenate; (2) that conjugation with related individuals is not merely useless, but destructive; as soon as they do this, says Maupas, their doom is sealed; (3) that rejuvenation is due to conjugation with unrelated individuals.

This work of Maupas had of course tremendous influence; it seemed to be definitive. There appeared to be no escape from his conclusions, and for many years they were hardly seriously questioned.

But in very recent times have come a series of investigations that have shaken the conclusions of Maupas and given the entire matter a new aspect. It appears to me that the time is ripe for a revision of judgment on the whole general problem of age, death and conjugation in these lower organisms. I shall attempt to give briefly the grounds for such a revision, and the direction which the final judgment must apparently take.

1. The credit for seriously opening the question anew, as well as for getting some of the most important evidence leading to what seem to me the correct conclusions, is due to Calkins in his investigations extending from 1901 to 1904. After cultivating *Paramecium* for about 200 generations (three months) without conjugation, Calkins found that they become depressed; the division rate decreases; many die. As you remember, he found that by changing the diet at these periods, by transferring from hay infusion to beef extract, to pancreas or brain extract—the animals could be revived, and their life and propagation continued. In this way he kept them for 742 generations (23 months), but at the end of that period they finally died, in spite of any changes that were made in their food. This showed that the infusoria could be kept alive without conjugation a much longer time than Maupas had observed. Calkins kept his animals for more than twice as many generations as did Maupas.

[2] See Engelmann, *Zeitschr. f. wiss. Zool.*, II. (1862), p. 347.

The results of Calkins's experiments can evidently be interpreted in two ways:

1. It may be held that the depression was due to a too great uniformity in the food, or to the fact that the food and other conditions were not fully adapted to the animals: what the organisms needed was a change of diet. With frequent changes in diet, perhaps, there would be no degeneration at all. The final death would, on this interpretation, be due to the fact that the injury produced by uniform diet had gone too deep to be remedied by the means which Calkins tried.

2. But Calkins inclined, in view of the evidence then at his command, to another interpretation. This work came shortly after the first portions of Loeb's brilliant investigations on artificial parthenogenesis. Calkins interpreted his results in the light of those experiments. He held that the infusoria were really in senile degeneration, ready to die of old age. What he had done was essentially to induce artificial parthenogenesis; he had replaced conjugation by chemical means. The final death, he held, was due to the fact that conjugation could not be indefinitely thus replaced; old age finally asserted its power, and in the absence of conjugation produced death.

Now I think it will be apparent at this point that there are two independent questions involved in the investigations; to understand later work it is needful to distinguish them clearly.

1. Does multiplication without conjugation result in degeneration, senility and death? What is the actual cause of the degeneration that has been observed?

2. Does conjugation remedy this degeneration? An affirmative answer to this second question has been generally assumed. If animals degenerate and die without conjugation, then evidently conjugation must be what prevents and remedies this result; such has been the reasoning. But if this is true it must be possible to *observe* this effect of conjugation; we shall do well to follow the example of Maupas, and not rest till a plausible hypothesis has been transformed into an observed fact.

These two questions then suggest two lines for further work, and both of these lines have been followed.

Enriques and Woodruff have followed up the question: What is the cause of the degeneration that has been observed? I myself have pursued mainly the second question, as to the actual effects of conjugation. The results of all these investigations seem to me harmonious and to lead to definite conclusions.

Enriques, in 1903 to 1908, carried out cultural investigations which led him to the following results and conclusions:

1. If he did not take pains to keep his cultures free from the products of bacterial action, the animals degenerated in time, just as observed by Maupas and Calkins.

2. But if he did keep them free from such products, by changing the fluid every day or oftener, no degeneration took place. He thus kept *Glaucoma* for 683 generations, without a sign of degeneration, and similar results were reached with other species.

Enriques concluded that the results of Maupas and Calkins are explained by these observations. In their experiments, he holds that the continued action of bacterial products was the cause of the degeneration.

Every one with experience in such work must I believe agree with Enriques that bacterial action is a most important factor in producing degeneration and death. But it seems clear that he was in error in holding that this is the only cause. The most significant feature of his results was the fact that he kept his organisms more than twice as long as did Maupas, with no degeneration whatever. He kept them for very nearly the same number of generations as did Calkins, but in the latter's cultures there had been several crises of degeneration, which finally ended in destruction. Enriques's work indicated strongly that this degeneration was not inevitable, though he may not have explained with full adequacy why it occurs. Enriques drew the general conclusion that there is no such thing as senile degeneration in these organisms; they might enjoy perpetual youth and live without end, if only the conditions are kept healthful.

Then came the work of Woodruff, with which you are acquainted; work which appears to be definitive for the part of the problem with which it deals. Woodruff investigated the possibility that the degeneration observed by Maupas and Calkins may have been due to too great uniformity in the cultural conditions; or to the fact that the conditions employed lacked something necessary to the continued health of the animals.

He therefore carried on a set of experiments wherein certain lines were subjected to frequent changes in conditions, while others were kept uniform. As you know, this gave the key to the problem. At last accounts, the progeny of a single individual were flourishing in generations subsequent to the 2,500th, after four years and three months, without conjugation. They had been at that time kept for about four times as many generations as had Calkins's culture when it died out, yet the animals in Woodruff's experiment showed no indication of degeneration. Later work by Woodruff seems to show that if only the culture medium is properly selected, no degeneration occurs even if the conditions are kept uniform.

The work of Woodruff demonstrates that the very limited periods within which Maupas and Calkins observed degeneration has no significance for the question as to whether degeneration is an inevitable result of continued reproduction without conjugation. In other words, it annihilates all the positive evidence for such degeneration, drawn

from work on the infusoria. It justifies the statement that the evidence is in favor of the power of these organisms to live indefinitely, if they are kept under healthful conditions. It shows that Weismann was correct in what he meant by speaking of the potential immortality of these organisms.

Thus I believe that we may feel that one of our two main questions has been definitely answered. Old age and death have no necessary place in the life of these creatures, even without conjugation.

But this brings the second question back to us with greater force than ever. What then is the effect of conjugation? What rôle does it play in the life of these creatures? Are we wrong in looking upon sexual union as a token of mortality?

This is the question to which I have addressed my own investigations, and with your permission I will speak next of these.

Before taking up directly the effects of conjugation, I would like to mention two subordinate points. First, in regard to the question that we have just discussed. Five years ago I started cultures from separate single individuals. During all that time there has been no opportunity for conjugation with unrelated animals, such as Maupas held to be necessary for continued life. Yet these cultures are still alive and flourishing. Thus the progeny of a single individual may certainly continue to multiply for five years without admixture from outside. This then agrees with Woodruff's results, save that Woodruff knows that there has been no conjugation of even related individuals in the line which he follows. But Maupas found, as we saw, that conjugation among the progeny of a single individual does not help, but is actually harmful: if such individuals conjugated, their doom was sealed.

But is this result of Maupas generally true? Is inbreeding among the progeny of a single individual injurious? Or did Maupas's animals die merely because they conjugated when in a dying condition?

To test this point, I caused the progeny of a single individual to conjugate together frequently. There was no evil result whatever from this. To carry the process to an extreme, I caused nine conjugations in succession within a single line, each pair being in every case the progeny of one member of the preceding pair. Thus the forefathers of the existing race have gone through the process of conjugating together nine times. Yet the progeny are as strong and well as ever.

It seems clear therefore that conjugation with close relatives is not harmful in itself, in these creatures, though repeated many times. It is of course possible that there are differences on this point among the infusoria, just as there appear to be among higher organisms. But it is certainly not a principle of general validity that inbreeding is harmful.

But now we come to the main question. What difference does conjugation make in the life of the race?

The way to test this question is to have a set of the animals of the same parentage and history; to divide these into two groups, and to allow one group to conjugate, the other not. Then keeping the two groups under the same conditions, what difference is found to be caused by the conjugation?

In carrying out such experiments, the control set, those that have not conjugated, are fully as necessary as the other; otherwise we can not tell whether the phenomena shown by those that have conjugated are really due to the conjugation or not. Neglect to have this control set has led to erroneous conclusions in some of the work previously done.

Comparative experiments of this character I have tried many times with large numbers of individuals. As the animals begin to conjugate, they first come in contact and stick together at the anterior end, though the process can not be consummated till the more posterior regions become united. At this point then I intervened, separated the two before union was complete, and removed each to a drop of water by itself. Other pairs were allowed to complete conjugation, then the members were isolated in the same way. The two sets were then kept under the same conditions and their propagation was followed exactly. The two differ in no other respect save that one set has conjugated, while the other has not. What difference is caused by conjugation?

1. We find that the animals which were ready to conjugate, which were actually attempting to do so, are by no means in a depressed, degenerated condition, unable to multiply farther. On the contrary, if they are not allowed to conjugate, each continues to multiply with undiminished vigor. Conjugation is then not necessary for further multiplication. And we can by no means assume that because individuals are ready to conjugate, they are therefore in a degenerate or senile condition. Nor can we assume, as has been done by some authors, that if the animals continue to multiply after conjugation, this shows that conjugation has had a rejuvenating effect, for the same specimens continue equally without conjugation.

This fact, taken in connection with the results of Woodruff, explains Maupas's supposed positive evidence that conjugation produces rejuvenescence, as also the more recent results of Miss Cull.[3] In Maupas's case, which is the one that has been mainly relied upon as demonstrating rejuvenescence, after the animals had become sickly (this being due, as Woodruff's work shows, to the fact that they had lived long under conditions not fully adapted to them), he tried mating one of them with a wild specimen. He then took one from this pair, and found that it was strong and well, so that it multiplied for 316 generations. Maupas supposed that this was due to the fact that conjugation had occurred. I believe it is fairly clear that the result was not due to the

[3] Cull, Sara White, "Rejuvenescence as a Result of Conjugation," *Journ. of Exper. Zool.*, 1907, 4, 85–89.

conjugation, but to the fact that he used a wild specimen, which had not been living under unadapted conditions. He apparently used the progeny of this wild individual for the remainder of his study. Now, the results I have just described show that if he had not allowed this animal to conjugate, it would have gone on multiplying just as well. Conjugation had nothing to do with the result, the fact that the specimen came from natural conditions is what counted.

Miss Cull's evidence for rejuvenescence consisted in showing that a considerable part of those that had conjugated continued thereafter to multiply. In the absence of the control experiment, she did not discover that they continue equally if they have not conjugated. There is then in this no evidence for a rejuvenating effect of conjugation.

2. To return to my own investigations, the second important result was to show that the specimens which have been allowed to conjugate multiply much less rapidly than those which have not conjugated. The difference is very marked, and showed itself in every experiment of a great number. The multiplication is slower, in those that have conjugated, for a month or two after conjugation.

This result seems surprising, in view of the widespread impression that multiplication becomes slower and slower, when the animals are kept without conjugation, and that the function of conjugation is to raise the vitality to the pitch where multiplication may continue at the normal rate. It is therefore interesting to note that those sterling investigators, Maupas and Richard Hertwig, knew well that conjugation does not increase the rapidity of multiplication. Maupas emphasizes and insists upon this fact again and again, at much length, in opposition to the prevailing view that conjugation increases the power of multiplication. What Maupas held was that conjugation saves the animals from death, though without increasing their reproductive powers. Richard Hertwig observed, correctly, that conjugation actually decreases the rate of multiplication.

3. A third result of comparing those that have conjugated with those that have not is that many more of the former die or are abnormal than of the latter. In a specially favorable experiment, out of 61 conjugants, eleven lines had died out completely in 33 days, while of 59 lines that had not conjugated, but were otherwise similar, none had died in the same period.

4. Usually a considerable number of the conjugants never divide after conjugation, while all of those that have not conjugated continue dividing.

5. There is much greater variation among the progeny of those that have conjugated than among those that have not. This greater variation shows itself (1) in the rate of multiplication; (2) in dimensions. If we determine the coefficients of variation, we find these much greater in the progeny of those that have been allowed to conjugate.

Thus from these experiments, repeated many times, on an extensive scale, there is no evidence that conjugation causes rejuvenescence. On the contrary, it appears to be a dangerous ordeal, which sets back the rate of reproduction; and results for many individuals in abnormalities and death. What conjugation seems to do positively is to produce a great number of varying combinations, some of which die out, while others continue to exist.

Before attempting to draw more fully the conclusions from these experiments, let us follow the investigations a little farther. In conducting an investigation it is necessary not only to satisfy one's self as to the correctness of a result, but also to meet the objections of those that are firmly of the opposed view. Now, to the results thus far set forth the following objections might be made. Conjugation, it could be said, may indeed be of no use, and even disadvantageous, when organisms are in a strong, healthy condition; they would doubtless do as well without it. Probably they conjugate many times when there is no necessity for it. Yet, it might be urged, if you did not allow them to conjugate at all for many times the usual period, then possibly the need of conjugation might show itself. If you had a race that was in a depressed, degenerate condition, from whatever cause, possibly you might find that conjugation would restore them.

I therefore next carried out experiments to determine whether this objection holds. A certain race of *Paramecium* conjugates as a rule every month or two. A culture of this race was divided into two parts. One part was allowed to conjugate every month, while the other was cultivated on slides and not permitted to conjugate. In this way the one set was allowed to conjugate four times in succession, in the course of a number of months, while the other set did not conjugate at all. We have thus a set that had missed four normal conjugations.

Now, as a matter of fact, the set that had missed the conjugations did become depressed: it multiplied slowly and irregularly, and many died. This may have been due, not to lack of conjugation, but to long-continued cultivation on slides; such cultivation does, of itself, produce an unhealthy condition. But in any case, we have now a depressed race and we can test the effect of conjugation upon it. Will conjugation end the depression, rejuvenate the organisms?

The experiment is performed by putting the members of this depressed race under the conditions that induce conjugation. Then, as conjugation begins, we permit one set to complete the process, while another lot is isolated without conjugation. The two sets are then cultivated under identical conditions. We have now an opportunity to determine the effects of conjugation on a depressed race, not complicated by any other differing factors.

The results were striking, and to a certain degree unexpected. All those that had not conjugated continued to be weak and sickly, and they

died out completely in the course of several weeks. Those that had conjugated showed great variation (as usual); some died very quickly; others multiplied very slowly and finally died out; others multiplied more vigorously than any of the non-conjugants. At the end of six weeks, all those that had not conjugated were dead, while certain lines of the others had multiplied and were numerous. The difference between the two sets was in fact very striking. But it is important not to misunderstand the nature of this difference. The lot that had conjugated showed great variation, and many of the lines were not stronger than the non-conjugants, dying out fully as quickly. But a few were stronger, and these multiplied and replaced the rest. Thus after some weeks, all the survivors had come from but three or four among those that had conjugated.

But even in these the depressed condition had not been completely overcome; they were still notably less vigorous than the strain which had been kept throughout under more natural conditions and had conjugated frequently.

Thus what had happened was this: Conjugation had produced much variation; some few of the variants had been more vigorous and had lived, while the rest died.

This result when first reached was unexpected and difficult to interpret. It seems of such importance that one felt it necessary to try it again. I shall not describe to you the long and wearisome process of providing anew the necessary conditions and repeating the experiment. It will suffice to say that the experiment was repeated and gave the same results as before.

Thus I believe that we are in position to make certain positive statements as to the effect of conjugation. Conjugation does not rejuvenate in any simple, direct way. What it does is to produce variation; to produce a great number of different combinations, having different properties. Some of these are more vigorous, others less vigorous. The latter die, the former survive. This happens equally, whether the animals which conjugate are at the beginning vigorous or weak. If they are vigorous, then one of the most striking effects of conjugation is to produce some lines that are less vigorous than the original ones, so that they die out. If the animals which enter conjugation are weak, then one of the most striking effects of conjugation is to produce certain combinations that are more vigorous than the original ones, so that they survive, while those that did not conjugate die out. In a short time the entire race is replaced by the descendants of a few of those that conjugated.

Now, the relation of all this to certain things that are known in higher organisms seems fairly clear. In higher animals likewise the result of intercrossing is to produce variation. We don't call it variation nowadays, because we know something more about it; we call it

Mendelian inheritance. In the crossing of two individuals that resemble each other externally, progeny of many different kinds are produced. In crossing white and cream-colored four o'clocks Correns got eleven kinds of red, white, yellow and striped offspring among the grandchildren. Heredity, as the Mendelian analysis has revealed it to us, is a process of producing a great number of diverse combinations by the varied intermingling of the characteristics (concealed or apparent) of two individuals.

Now, it seems clear that this is exactly what is done in the conjugation of the infusoria. We have not yet succeeded in determining the precise rules of recombination, such as have been worked out for many cases in higher organisms; so that for the infusorian we are as yet limited to the statement that conjugation produces variation.

Thus the conjugants apparently have the same relation to each other, so far as inheritance is concerned, as do sperm and egg in the higher organisms. We ought to find that the progeny inherit from both of the conjugants. What are the positively known facts as to this?

Regarding biparental inheritance in these lower animals, we are as yet in that relatively backward stage of science that is implied by the necessity for the use of statistical methods.

We hear at times the Kantian dictum that any subject is scientific only to the extent that it makes use of mathematics. This dictum is sometimes put before us as an argument for using statistical methods. But for these we could almost reverse the statement, and say that any subject is scientific only to the extent that it can dispense with statistical methods. These are necessary mainly when we can not understand and control the separate causes that are at work; as soon as we can do this such methods become largely unnecessary.

But the use of statistical methods enables us to show that in conjugation the progeny inherit from both parents. By working out for the rate of fission the coefficient of correlation between the descendants of the two that have conjugated, we find that they have nearly the same closeness of relationship as brothers and sisters; and somewhat closer than cousins. The coefficient of correlation is about .4. This means that if the progeny of one member of a pair have a peculiarity, the progeny of the other member have the same peculiarity, though in a less degree, and this similarity can apparently come only through inheritance from both parents.

Comparing conjugation with the fertilization of higher animals, we find then this state of the case. In higher animals fertilization has two diverse effects, which recent investigation, particularly that of Loeb and his associates, has clearly disentangled. (1) On the one hand, it initiates development; it prevents the egg from dying, as it would do if not fertilized. This function of fertilization is the one that is replaced by the processes which induce artificial parthenogenesis.

(2) But, secondly, fertilization brings about in some way inheritance from two parents. When there is inheritance from but one parent, the inheritance is as it were complete; the child as a rule resembles its parent in all hereditary characteristics; this is the result of the so-called "pure line" work. But when we have biparental inheritance, a great number of different combinations of the characteristics of the two parents are produced, so that the process of fertilization is one that in this respect completely alters the face of organic nature, producing infinite variety in place of relative uniformity.

These two functions of fertilization, the initiation of development, on the one hand, the production of inheritance from two parents, on the other, are logically independent: they might conceivably be performed at different times and by different mechanisms. The fact that in many organisms the same mechanism that brings about biparental inheritance is likewise the one that initiates development might from certain points of view be called an adaptation. Its result is to insure that in *all* the organisms that develop there shall be inheritance from two parents, not from one. In the work on artificial parthenogenesis these two functions have been separated experimentally; the initiation of development takes place alone.

Now, in endeavoring to understand conjugation, attention has been given hitherto almost exclusively to the first of these two functions. It was held that the function of conjugation must be to make possible life and development where it was otherwise impossible, just as fertilization arouses the egg to further life and development. But it turns out that conjugation, instead of having this one of the two functions of fertilization, has the other. The two functions are in the infusorian separated, just as they are in artificial parthenogenesis, but it is the second, not the first, that we have before us. Conjugation is not necessary in order that life and reproduction shall continue; they continue without it.

But the life which thus continues is uniform and unchanging. To give biparental inheritance, with varying mixtures of the characteristics of the two parents; to produce these new combinations in great variety, conjugation is necessary. And when this happens under such conditions that the original combinations were not adapted to survival, then some of the new combinations produced often are adapted to the conditions; conjugation then results in a survival of an organism that would have been completely destroyed without it. It is most interesting in this connection to observe that conjugation is usually induced by an unfavorable change of conditions, a change of such a nature that the organisms begin to decline. Thereupon conjugation occurs, so that new combinations are produced, adapted to varied conditions, some of which may survive.

Thus it appears to me that the whole series of investigations on old

age and on conjugation leads to a unified result, and one that is in most respects in consonance with what we observe in higher animals. But in one respect there is a difference, and this brings us back to the question with which we began. Is death a necessary accompaniment of life? Do the life processes necessarily take such a course that they must lead to death?

To this question the work on the infusoria answers *No!* The evidence that was supposed to show that the life processes must gradually run down and end in death had been shown by the work of Woodruff not to lead to any such conclusion. Woodruff appears to be clearly justified in his recent statement that these organisms "have the potentiality to perpetuate themselves indefinitely by division," and my own studies on the effects of conjugation furnish the complement to this result, agreeing with it fundamentally.

All that Weismann meant by saying that such creatures are potentially immortal has shown itself correct. Death is not necessarily involved in life.

But why, then, in higher animals and in ourselves, even when there is no accident and conditions are good, do we find death coming as a natural end to life? Why should there be this tremendous difference in such an essential point between the lower organisms and the higher ones? Is there any possibility of mistake as to the necessity in the case of higher organisms?

To find a ground for this difference, we shall do well to follow the usual procedure in science, and examine other differences between these lower creatures and the higher ones, to see if these may not give us the clue. And here I touch upon a matter that had been fully developed by Minot and others; it is worth while to speak of it briefly, because work bearing upon the matter has recently appeared.

The most striking other difference between these lower organisms and the higher ones, is evidently the fact that in the higher organisms the body becomes large, complex and differentiated into a number of diverse parts; different cells of the body have taken on themselves different functions and different structures. This appears to involve a correlative loss of the power of carrying on the fundamental vital processes; the cell that has become filled with lime, or that has transformed into muscle, no longer retains the vital elasticity of the cell in which the diverse functions remain well balanced. Products of metabolism are no longer perfectly removed; other processes necessary to life become clogged. The final result of this is a complete cessation of the processes; age and death follow upon differentiation. This, as you know, is the theory of Minot. According to it, the welfare of the individual cell is as it were sacrificed to that of the body as a whole, and this in turn involves the final destruction of the body itself, so that a

period of higher diversified life is purchased at the price of ultimate death.

Minot has added to this fundamental idea certain views as to quantitative relations of nuclear and cytoplasmic material in the cell. Relative increase of cytoplasm is taken to be the beginning of the process of aging, while relative increase in nuclear material is considered a process of rejuvenation. Such rejuvenation was held therefore to occur in the early cleavage of the egg, since here the amount of nuclear material was supposed to increase greatly in proportion to the amount of cytoplasm.

The recent important paper of Conklin has shown that in the cleavage of many animals this increase of nuclear material relative to the cytoplasm does not occur. Conklin's results will apparently go far in rendering untenable or modifying all theories in which great significance is attached to the precise quantitative relations between nucleus and cytoplasm. But what is important to realize is that this has no bearing on the fundamental feature of the theory that aging and death are due to differentiation. The grafting of the theory that the quantitative relation between nuclear and cytoplasmic material is an essential point upon this general theory was unfortunate from the beginning.

Everything points, it appears to me, to the essential correctness of the view which holds age and death to be the result of the greatly increased differentiation of larger organisms. Is there then any probability that we shall some time find that in the higher animals, as in the lower ones, death need not occur?

Evidently not. If death is the price of differentiation, then after the goods have been delivered the price must be paid. To prevent a higher organism from undergoing death would at the same time prevent him from becoming a higher organism. And the cell which remains in the embryonic condition—the cell of the germ glands—is even now as immortal as the cell of the infusorian. Death, as Minot says, is the price we pay for our more complex life. Age and death, though not inherent in life itself, are inherent in the differentiation which makes life worth living.

CONSERVATION IDEALS IN THE IMPROVEMENT OF PLANTS

By Dr. H. J. WEBBER

NEW YORK STATE COLLEGE OF AGRICULTURE, CORNELL UNIVERSITY

THE conservation movement had its inception in the wasteful methods practised in the utilization of our national resources, such as our forests and mineral deposits. Alfred Russel Wallace, the great English evolutionist and contemporary of Darwin, has characterized the last century as a century of despoliation of the natural resources of the earth. Our forests have been ruthlessly destroyed until good lumber has reached a very high price, and turpentine and resin in sufficient quantities to meet the world's requirements can scarcely be obtained. In the meantime large areas, denuded of forests, have been changed in climatic conditions and the fertile soils exposed to destructive erosion. Coal beds are being worked in ever increasing quantities and must ultimately be exhausted. The Chilean nitrate-of-soda deposits are approaching exhaustion. We use without thought of the morrow. The conservation movement has extended to the consideration of soil fertility, the proper utilization of water, of water power, of our land domain, and the like.

There is scarcely any source of wealth or of material necessities that has not felt the influence of the conservation movement. If we seek the real source or reason for this inquiry, it is to be found in the rapid increase of our population. The arguments are too familiar to require repetition. We all know that the population of this country and of the world is increasing so rapidly that the time is not far distant when our children will have great difficulty in producing the necessary supplies to maintain life. The teeming millions of fifty and one hundred years hence will not have the rich, virgin lands on which to extend their agriculture, the primeval forests, the apparently inexhaustible coal beds, the extensive deposits of phosphates, nitrates and potash salts, to use in rebuilding their soils. All these sources of supply that we have utilized and found so necessary to life will be gone or rapidly disappearing, and the extent of the demand will meanwhile have increased many fold. It takes no very extraordinary vision to picture the fierceness of the struggle for existence that must soon be reached in the development of the human race. True, there is no immediate concern, as the world will comfortably support a very much larger population; but to preserve future generations from danger requires the wise action of the present and succeeding generations. The careful study of the

problem in all its phases is a duty that we can not shirk. The high cost of living at the present time and the simpler living that thousands of families have been compelled to adopt is a reminder of the necessity, even to the present generation, of a careful study of the existing conditions.

The problem of all problems confronting us is the necessity of increasing the production of food stuffs. How can this be done? Obviously the problem can be attacked from many sides, but the side that I desire to emphasize is the conservation of the best breeding stock of plants and animals. This seems a simple matter, but I am sure that the far-reaching possibilities of such conservation are not understood and are beyond our conception at the present time, as our viewpoint is necessarily limited by our present knowledge. Nevertheless, as judged by our present knowledge, the possibilities are so great as to place this factor, I believe, among the important features of the conservation movement.

What do we not owe to our domesticated and improved plants and animals? They are the greatest heritage that has come down to us from our ancestors. If the cultivated varieties and breeds of wheat, oats, corn, cotton, potatoes, cattle, sheep, hogs and horses were all destroyed from the earth and we were forced to go back to wild nature and begin the improvement over again, it is probable that the world would be almost depopulated and that the progeny of the few hardy individuals that survived would, in the centuries that followed, repeat the history of plant and animal improvement that has taken place in the past. Doubtless, however, new plants and animals now unknown to us would be the successful ones in the new evolution. That we now cultivate wheat, oats, corn and the like is probably in large measure due to the accident that attempts to artificially cultivate plants started in regions where the wild ancestors of these plants were native.

In many cases the wild ancestors of our cultivated plants are not positively known. It is not probable that the ancestral types have become extinct, but that the cultivated forms have been so greatly modified that the relationship can not now be recognized with certainty. If *Ægilops ovata*, a wild grass of southern Europe, is the original ancestral form of wheat, as is supposed by some botanists, we have very many native grasses in various parts of the United States, which in an unimproved state have much larger grains and would seem to be equally worthy of cultivation and improvement. If Teosinte (*Euclæna luxurians*), a wild native grass of Mexico, is the original wild ancestor of corn, as is believed by many scientists because of the fact that it is a native of the region where corn was first cultivated, is known to be subject to the same diseases, such as smut, and above all from the fact that it hybridizes readily with corn, we have an unpromising grass, so far as its

grain is concerned, which has developed into our greatest of all grain crops.

Are we correct in assuming that all of the valuable plants and animals have already been introduced into cultivation? As a matter of fact, are we not justified in questioning whether the most valuable have been introduced? On sober second thought, does it not seem wonderful that wheat, a native of the Mediterranean region, should remain the best grain crop for a region including the greater part of British America and the United States, of Russia and Argentina and all the broad area where wheat is cultivated? Would it not seem probable that the improvement of the most promising native grain-grasses in these widely different regions would yield new types of grain crops better adapted to the regions and superior to wheat or oats? The great value of wheat and oats lies not in the superiority of the wild types from which they sprang, but to the long years of cultivation and selection to which they have been subjected. A large number of wild grasses occurring in almost every region have comparatively large grains, and if they were capable of improvement, as they doubtless are, they might possibly excel any grains that we now have. The Indian rice or water oat (*Zizania aquatica*) is an illustration of a large-grained wild grass that is probably known to many. Doubtless this could be greatly improved for cultivation in low lands as rice is now cultivated.

The wild wheat grass (*Agropyrum occidentale*) of the great plains region is a very promising type for improvement, as pointed out by Dr. Bessey.[2] In this wild grass we have a head 5 or 6 inches long and developing long, narrow grains much resembling wheat. It is a perennial and grows to a height of 2 or 3 feet. Dr. Bessey says of this plant:

> If our plant had had but a fraction of the careful cultivation and selection which have been given the European species, I am confident that it would have yielded a much more productive cereal than we have in our present varieties of wheat.

Consider further that we have here a perennial that would doubtless yield for several or possibly many years without reseeding, and also that it is a native of the great plains region and thus already adapted to the environment of the great wheat states of the union. Comparing this grass with wheat, which should we expect to be better adapted to the "dry farming" regions of the west?

Several of the wild rye grasses (*Elymus*) have large heads and grains and appear very promising, as do also certain species of the so-called beard-grass (*Andropogon*).

We have only considered the value of these grasses from the standpoint of their grain development; but it is of almost equal importance

[2] Bessey, C. E., "Crop Improvement by Utilizing Wild Species," American Breeders' Association, Vol. II., p. 113.

to consider their value as forage crops for animal food, and here a much greater latitude for selection is possible. A very large number of our native plants should be tested and the most promising improved for forage purposes.

In the development of leguminous crops we have a valuable field of research. Of the many hundreds of legumes, we now cultivate only about a dozen species, such as beans, peas, clover, alfalfa, crimson clover, cowpeas, soy beans and the like, representing a natural adaptation to as many localities. None of the species ordinarily cultivated in the northern United States are natives of this great section. Yet an examination of the botanies shows that some 150 different species of legumes are natives of this section. Would it not seem absurd to assume that our present cultivated species represent the best types for this section, when the most promising of those that the great Master Breeder gave us have not been thoroughly improved and tested? Among the wild native species of *Desmodium, Vicia, Lespedeza* and other legumes, we have a number of promising sorts. We have tested many of these species in comparison with our ordinary cultivated crops and discarded them, but our tests have been of the wild, unimproved, against the improved types. We might as reasonably put gloves on a wild pygmy of Africa and test him on the mat with a trained modern athlete.

Doubtless the mere mentioning of the improvement of native plants suggests to the minds of each one of you some wild plant that you have observed and thought to possess valuable qualities. If our sources of nitrogen supply are to be exhausted soon, we must cultivate more leguminous crops that can gather their own nitrogen and improve the soil in this respect while furnishing crops. We should have leguminous tuber crops to take the place of potatoes, beets and turnips. Nature has given us such wild legumes as the groundnut (*Apios tuberosa*) and the Pomme de Prairie (*Psoralea esculenta*), which already have edible tubers and which could doubtless be developed into very valuable cultivated plants by a few years of breeding.

Dr. J. Russell Smith,[3] of the University of Pennsylvania, has emphasized the importance of breeding tree crops, and here we have an inexhaustible field of experimentation. We should breed chestnuts, walnuts, hickories, oaks, beeches, hazelnuts, and the like, in order to improve them for the use of man and for growth as stock food. Many hundreds of thousands of acres of rough, hilly land unadapted for cultivation would be suited for the growth of such crops.

The possibilities of breeding tree crops are well illustrated by the excessive increase in vigor, rapidity of growth and size of fruit obtained by Burbank in a hybrid between the English walnut (*Juglans*

[3] Smith, J. Russell, "The Breeding and Use of Tree Crops," American Breeders' Association, Vol. I., p. 86.

regia) and the California black walnut (*J. californica*). Burbank says:

> The hybrid grows twice as fast as the combined growth of both parents. The leaves are from 2 feet to a full yard in length. The wood is compact, with lustrous, silky grain, taking a beautiful polish, and as the annual layers of growth are an inch or more in thickness and the medullary rays prominent, the effect is unique.

Another of Burbank's walnut hybrids obtained by crossing the black walnut with pollen of the Californian black walnut, produces fruit of very much larger size than either parent. When we come to plant large areas to trees, as we are rapidly coming to do, imagine the immense value to the world if we could plant hybrids of rapid growth such as Burbank's walnuts.

Who has tried to produce hybrids of maples, oaks, hickories and pines to get quick-growing hybrids for planting purposes? Who has hybridized such trees to get larger and better fruits? The world should not be compelled to wait much longer for such improvements. We need the improved stock for planting. Some trees live a century before they reach young manhood.

Persimmons, pawpaws, huckleberries, elderberries, hawthorns and hosts of other native fruits are well worth improvement and might be utilized not only for human food but for hogs, sheep and poultry.

Mr. Frank Babak, of the Department of Agriculture, has recently shown that the black sage (*Ramona stachoides*), a wild California plant, and the swamp bay tree (*Persea pubescens*) of the southeastern United States, both contain a fairly high percentage of camphor and could be utilized for the manufacture of this valuable product. Doubtless these plants could, by breeding, be adapted to cultivation and the percentage of camphor increased.

The value of improving native plants has been strikingly demonstrated by the amelioration of our native grapes. The attempts of our early ancestors in America to grow European grapes uniformly met with failure, and finally, as a last resort, attempts were made to cultivate the native wild types. The marvelous success achieved, which has resulted in the production of a large number of fine varieties, and established vine growing in the eastern and central United States, is one of the important achievements of our many-sided national history.

The same was true in the case of the gooseberry. The European varieties failing to succeed here because of the mildew, the small fruited native species were introduced into cultivation, and the size of the fruits has been more than quadrupled in the improved sorts. Plums, raspberries, blackberries and the like furnish other illustrations of interest.

The native wild beggar weed (*Desmodium tortuosum*) has been introduced into cultivation in Florida, and, without breeding or im-

provement of any kind, has in a few years won a permanent place in southern agriculture.

It may be argued that the improvement of our native plants would be too slow to justify attempts in this direction. I should answer that nothing is too slow that will pay. Nations bond themselves for hundreds of millions of dollars to carry on a war of the present, which bonds their children must pay sometime in the future, and for no compensation except to maintain the pledged honor of the nation. While breeding is slow when judged from the "get-rich-quick" standpoint of modern Chicago, it is not slow when compared with the life of a nation and from the standpoint of permanent welfare. Within the memory of man the tomato has been introduced into cultivation and advanced in size from a fruit of $\frac{3}{4}$ of an inch in diameter to our fine modern fruits, some of which grow as large as 4 inches in diameter.

A striking illustration of this nature is furnished by the experiments that the writer has conducted in the improvement of timothy. Timothy was introduced into cultivation about 1720, nearly two centuries ago. For many years it has been extensively grown, but, until recently, no attempts have been made to develop improved races. In experiments conducted by the Cornell Experiment Station, timothy seed was obtained from a large number of places in this and foreign countries, from which about 18,000 individual plants were grown and the different types studied and isolated. As a result of 9 years of work, some 200 different races have been secured that show a very wide range of characters, and vary from dwarfs to giants in size. A test of the yields of 17 of these new varieties in comparison with the best timothy seed that could be purchased in the market was made in 1910, and also in 1911. In 1910 the average yield of the 17 new sorts was 7,451 pounds per acre and that of the 7 check plats of ordinary timothy was 6,600 pounds per acre; an average increase of 851 pounds per acre in favor of the new varieties. In 1911 the average yield of the 17 new sorts was 7,153 pounds per acre and that of the 7 check plats was 4,091 pounds per acre; an average increase of 3,062 pounds per acre in favor of the new varieties. Four of the high yielding sorts in 1911 gave an increased yield of over 2 tons per acre, or practically double the average yield of the checks, which is an astonishing figure and can be explained only by the fact that timothy has never been improved by breeding and still consists, as generally cultivated, of a motley array of many different types.

Hay is one of the largest agricultural crops of the United States, outranking all other crops, except corn, in total value of production. In 1910, according to the statements issued by the United States Department of Agriculture, there were grown in the United States 45,691,000 acres of hay, which yielded a crop having a farm valuation of $747,769,000. No statistics are available from which we can determine

what proportion of this hay was timothy, but the writer believes that we may safely conclude that at least one third of the entire hay crop of the country is timothy. If this is true, the timothy crop of the United States in 1910 had a valuation of over $249,000,000. In the two years during which tests have been made, the 17 new sorts gave an average increased yield of slightly over 36⅗ per cent. above ordinary timothy. A 36⅗ per cent. increase in the valuation of the timothy crop as above estimated would give us over $90,000,000 as the estimated annual gain in the value of the crop which would be obtained if new sorts equally as good as these could be used throughout the country.

The rapid development of the science and art of breeding places us to-day in position to secure improvements much more rapidly than has been done in the past. It would not be astonishing if from 25 to 50 years of careful, intelligent breeding would accomplish with a wild plant what has required many centuries under the crude methods of our ancestors.

It may be asked why we should be in haste to take up the improvement of our native plants. In answer to this it may be stated that profound changes, such as we desire and must have, require time for their accomplishment. The potato and the tomato did not reach their present perfection at one bound. A number of intermediate stages or improvements were first necessary. The strawberry and the gooseberry did not reach their present size by one mutation, but several intermediate sizes were first necessary. Improvements apparently come by sudden leaps or mutations, and each of these paves the way for further development that might never be possible without the first improvement.

In breeding, the time element is the limiting factor of importance. No permanent improvement of value can be obtained in a day, and no time should be lost in beginning, on a scale commensurate with its importance, the improvement of our native plants of promise. We must conserve time and fulfill our duty to the succeeding generations. Why is it that such a small proportion of our lands are cultivated? According to the 1900 census, of the 1,900,000,000 acres of land in continental United States only 838 millions of acres were in farms, and of this area over 50.6 per cent. was unimproved land. The sterile sandy lands, and the low, wet lands, the stony lands and the hill lands, the mountain lands of high altitude and the barren lands of deserts lacking water, and the like, all uncultivatable and largely worthless for crops at present grown, make up far the larger part of our vast domain.

Travel through the high, hilly and mountainous regions of New York, Pennsylvania, Maryland, Virginia, North and South Carolina and Georgia, and you find vast areas covered mainly with a low growth of young trees and bushes, the main forests having been removed. The same is true of many extended areas in the central and western states.

The utilization of these waste lands forms one of our great national problems, and the beginning of the solution of the problem rests in finding the crops best adapted to such areas or in all probability in breeding crops that will be adapted to them. The necessity of using these waste lands in the near future is evident. Shall we plant them to forest? Certainly much of this land should be in forest, or in tree crops of some sort, but we want tree crops, at least in many cases, that will return food as well as shelter. The Italian yield of chestnuts is said to average 12 bushels per acre, and J. Russell Smith states that "the value of European mountain-side chestnut orchards equals acre for acre the Illinois corn belt." The kinds of trees to plant in such areas for wood, fruit, sugar, starch, camphor or forage require careful study and the proper breeding in order to secure the best sorts possible.

But this is not all of the problem. Grain, forage and special fruit crops, not necessarily forest trees, require to be as carefully considered, and here again breeding to secure good races adapted to the conditions will be the key note of success. All this requires time, and the generations to follow will not have the time and certainly not the money if they do not repudiate our war debts. The work should be started immediately in order to obtain the results by the time conditions demand them. When I urge this as one of the important national problems of conservation, I speak not without some authority. My life has been given to agricultural work in various parts of the United States. My boyhood on an Iowa farm gave me a knowledge of the rich prairie regions of the west. My education in the University of Nebraska and Washington University, Missouri, extended that knowledge. My sixteen years of service in the National Department of Agriculture, working with cotton and oranges in Florida, Georgia, Alabama, Mississippi and Texas, taught me southern conditions and demands, and now my experience of the last five years in Cornell University, associated with that master agriculturist, Dean L. H. Bailey, has broadened my horizon to at least some conception of the field of agricultural education.

As to the possibilities of producing the suggested improvements in plants, it again may be granted that I can speak with some degree of authority in view of the fact that the great cotton, corn, timothy, orange and pineapple industries have, at least in certain places, felt the influence of new varieties that have gone out from my laboratory. I say this not to extol myself, as any man in my place with my opportunity could have accomplished the same results and many would have done very much more. I say it simply to lend weight to my statements.

I can by no words of mine present this problem in its importance as I see it. In no way, probably, can my efforts stir the nation to a recognition of the necessities of this case, so that action will not be too long delayed. Recognizing the urgency of the problem as I do, how-

ever, I should be remiss of my duty did I not use such powers and gifts as have been given me to urge forward a project that sooner or later will be recognized as one of the keystones of the conservation movement.

The materials for the consummation of the ideals I have presented are all around us. The brawn and brain for the service is awaiting the opportunity. The service will be long and difficult, however, and the servant must live while engaged in the task. Only by long, consecutive years of service can the highest ideals be reached. Men must consecrate their lives to this achievement. The service will be pleasant and the scientific results gathered from year to year will repay the worker, but means must be found to place the investigator beyond the temptation of other employment, as permanency of tenure in such work will be of the highest importance. It is a work for the state and the nation, but I fear they will be too slow to recognize the long-time requirements of the work. Political institutions demand too quick results. I feel that the most hopeful method of accomplishing some of the ideals outlined is through endowed institutions. To what more serviceable task could benefactions be devoted than to the solution of such problems, and what type of institution would return more credit to the donor? Institutions to conduct such work could be tied up with some of our great universities to establish the proper scientific relationship, and should be in such close cooperation with these universities that graduate students could be utilized in connection with the investigations and trained in the service.

In summarizing this discussion I may say that to one unfamiliar with the possibilities of breeding the outcome of such experiments may appear doubtful. We need no lamp to guide us except that of experience. When we realize the little promise exhibited by the native grapes, tomatoes and potatoes from which our cultivated sorts have sprung, we gain a conception of the tremendous increases that can be brought about by a century of cultivation, even when the breeding is of desultory nature. Couple with a century of time, aye fifty years, the skill of trained breeders, and what might we not accomplish. The greatness of the possibilities stretches before the enthusiastic breeder as his mind spans the years filled with the battles of conquest and achievement in the building up of new industries, like a panorama of the wars and struggles in the building of a nation. Man's creative genius is touched. It appeals to him in its vastness as a challenge. The trained man in the field of breeding feels the certainty of his power. He longs for the conquest.

A PHILOSOPHY OF GEOGRAPHY

By Professor WALTER EDWARD McCOURT
WASHINGTON UNIVERSITY

IN the minds of many persons to-day it might seem necessary to apologize for holding to a "philosophy of geography," that study often remembered from school days with either utter dislike or disinterest; for in early years it was a bugbear to carry about the "big geography" in between the covers of which were gathered the colored maps of the various countries, with descriptions of those countries and their boundaries, products, exports, imports, rivers—a real Baedeker of the earth. Even later most of us were hurried along, not given time to catch our breath or have our wonders satisfied; and to-day, perhaps, there are still some who wonder at the college professor's giving serious thought to a subject of which they learned all there was to be learned during the years of schooling.

But such remembrances are probably becoming fewer, for in the minds of many thinkers to-day there is no doubt that the science of geography is one which furnishes much food for thought and much opportunity for research. Not only in the works of many of the older thinkers and philosophers, but also in the pages of various current periodicals and in some of the excellent modern histories, may one see something of the attitude which endeavors to view many human activities in their relation to the geographic stage. From making the study of geography dwindle into a mere recital of fact—with what hours of dullness or dryness!—it may be of interest or profit to somewhat fully give to geography a place beyond that of a mere catalogue of distribution, and to enrich its apparent field by glancing at some of its interesting causes and tremendous effects.

As was suggested, the mental image called forth by the word geography would doubtless be to many a mass of disconnected details, dealing chiefly with the idea of localization and definition and the remembrance of things in themselves uninteresting. An island was a mass of land entirely surrounded by water. An isthmus was a neck connecting two large areas of land. Why the island existed, or how it came about were "hideous secrets." Why two bodies were connected by a constriction may have been a mystery, and one was never led to solve it. "What was the capital of Missouri?" "For what product was Iowa famous?" "What crop comes from the northern plains?" "Name ten large cities of America." No one thought of enlightening the, perhaps,

curious minds as to why the ten largest cities were largest. They merely were. No one tried to tell why the great wheat plains were plains. They just were. Yea, verily have many been piloted about the earth, passing with kaleidoscopic haste picture after picture, cramming their heads with encyclopedic facts until they were made aching by the rush of detail. Truly were they as the summer tourist with red Baedeker in hand, seeing and learning.

Geography is not a mere placing of things upon an earth. It is not a subject fit only to be placed in childhood's curriculum and passed through hurriedly during immature years. Geography ought to awaken an interest and kindle an enthusiasm rivaled by few other sciences, to all minds, the mature as well as the young, because of its far-reaching relations. What about the romance of the forces of the earth, the beauty of topographic expression? Why not see in the tiny trickle of the rain gully the roaring, destruction-bearing Colorado? or behold in the frozen cap of the pond ice the wasted expanse of Greenland's glaciers?—or picture in the muddy sidewalk the tons of débris dumped by the Father of Waters at New Orleans to add new lands to the old?

Vermont may be a great producer of slate. But why? What a story a piece of Vermont slate might tell!—of a time many thousands of years ago when beneath the sea were being deposited muds worn from the land beyond. Then, deeply buried beneath overlying sediments, the clay became pressed to a firm shale. In the turning and folding of the whole mass to make new land, the heat of the disturbance baked the shale, and the pressure of the overlying rocks developed in it the fine planes of cleavage; the shale became a slate. And the wearing of the rocks above by the processes of erosion brought to man's view the roofing of his home! Then, too, compare the passionate temperamental Italian with his more stable and phlegmatic cousins of the north. Is it just "the nature of the beast"? or is there a "why"? Why is the oriental art so rich in all its riot of color? Why the prominence of Philadelphia, Chicago, Richmond? Why the steel rails of Pittsburgh?—the great fruit produce of New York?

These and many like questions may give an insight into the "different" way of thinking of geography. For, although all of us will admit that what we have or are is because we are of the earth's food, shelter or clothing—the three R's of life—yet I want to suggest some of the perhaps less well known but just as interesting correlations between ourselves and geographical conditions.

The earth supplies man with the necessities of food, clothing and shelter, which, naturally, differ in different parts of the world. And yet in each locality man has adapted himself to these differences. The

relationship of man to the physical things of the earth is one which can be traced out in the minutest detail, especially, of course, in primitive communities where food is absolutely dependent upon geographic location. The Esquimaux, with no forest or sandy deserts, eat of fish and game. The fruits supply the tropical savage, there where the warm climate supports a variety of vegetable life, so that the native has but to step from his grass hut to find his daily bread. Pastoral peoples have their milk foods, dwelling as they do in the sweeping plains of Australia or Russia which support flocks of sheep and herds of oxen. Moreover wheat, corn, maize, meat, which are all products of the physical earth, of climatic and geographical conditions, go far to shape the man of the temperate zone.

Likewise, compare the leather garments of the shepherd, the fur coat of the Lap, the woolen garment of the Russian, the grass dress of the Australian, and see in them the influence of geography. Or, trace in the adobe hut of the plainsman, the sod homes of the tropical savage, the inglow of the Esquimau, and the skin tents of the nomads, in the carved stone buildings of the cave dweller, in the log hut of the forester, in the cobble house of New York state, a like influence of geography upon the sheltering places of man.

As for occupations, does not one see in the hunting of the African wilderness, the herding on the plains of Patagonia, the agriculture of the river valleys, the mining of the mountains, the lumbering of Canada, the fruit growing of California a relationship with the geographic field? When a community possesses more material than can be utilized by it, peoples begin a trade, thus establishing commercial relations, with the development, on a large scale, of agriculture, manufacturing and other industries. Man would not have made rugs in India, for there was no wool. Nor would he have made gold ornaments in England, for there the gold was absent. The Persians made rugs, for wool was at their door; the Hindoos carved gems, for Indian plateaus were pregnant with them; the Chinese wove costly silks, for in their country the silk worm flourished; the Norsemen built boats, for in their country lumber was cheap. In short, in many places, as raw materials were present, so manufactures grew—porcelain in Japan, rugs in Persia, ships in Norway, pottery in England, steel in Birmingham, smelting at Denver, cement in New Jersey. Power is needed in extensive manufacture, and where power is cheap or easily obtainable there may arise immense industrial centers, as at Birmingham, Pittsburgh and Niagara Falls—where fuel is at a stone's throw away, or where the mighty rush of water furnishes energy, and where it is often comparatively cheap to bring, for manufacture, raw materials produced elsewhere. Often, too, where places are favorably situated along travel lines of least resistance there may grow up populous centers as Buffalo, Saint Louis, London and New York.

Let us now view a few more historical facts in this limelight of geography. The history of geography, which leads to the geography of to-day, is a record of achievement, colonization, trading, conquest, religious zeal, and scientific endeavor. The nomads move because the environment will not support them. Disturb an environment and see the result. Block the trade route from Europe to Cathay as did the Turks and a new world is discovered. Block this route and Venice trade passes into the hands of Portugal. Pierce the Isthmus, and Japan is at your doors. As Keltie has so well pointed out, the first great civilizations, Babylonian, Egyptian, Chinese and Indian, began in the great river valleys. They were non-cosmopolitan and isolated civilizations, for they were content in the fertile valleys of the Nile, Euphrates, Ganges and Yang-tse-Kiang. Contrast with theirs the spirit of the Phœnicians, the sturdy and fearless seamen of the pre-christian era, forced to trade by the non-fertile condition of their strip of country. See the physical development of the Greek, his intellectual stimulus inspired greatly by the multitude of topographic conditions. How did the Himalayas affect history?—serving as a barrier, hindering the migration of both man and beast, and protecting the people from invasion? Among mountain people many ancient customs are preserved. Because the Scotch and Welsh were much less affected by invasion than other parts of the British Isles during time of inroads, some of the oldest of their dialects still linger with them. The *Basques,* a small body of people in the Pyrenees, still speak a language spoken by no other race. Why has Switzerland been able to remain independent? Because the brisk air of mountains helps to develop a brave, hardy people, and because of her impregnable position among the Alps. Why did the early American settlers locate along the Atlantic coast and not push towards the west? The Appalacians served as a barrier to the spread of the early colonists and sheltered them from the savages of the west. Why was Alaska exploited? The gold in her gravels. England owes much of her historical importance to the geographical fact that the sinkings of the land give the coast such an irregularity of outline as is always favorable to the development of navigation, commerce, fishing. Why has Austria been from time to time the scene of inroads by Asian peoples? Because she lies open to the Black Sea and the plains of central Europe.

Man, with certain limits, differs from his lower cousins of the animal family by being able to take his environment by the forelock and make use of it for his own convenience. He constructs a Suez canal, he removes a mountain from his path by carving a Simplon tunnel, he brings fertility to arid New Mexico; he drains Arkansas swamps, he rescues Holland from the sea, he changes the course of the Mississippi. Indeed, it may seem bold, but there is much truth in the statement that the greatest enterprises of the present day are the results of wise utilization of geographic knowledge.

It is to the astronomers and mathematicians, glued to their telescopes or buried in their complex calculations, to whom we must go for knowledge of the magnitude of the earth, of ways of locating points, of reasons for climatic conditions, and day and night. And so geography, as a science, is related to their subjects. Probably the plains of Chaldæa and Babylon were the primal seats of observative astronomy. For there the unbroken plains of Mesopotamia could not arouse enthusiasm, but the phenomena in the heavens, changing with the days and the seasons, would most assuredly attract attention. Besides, the level expanses and the clear atmosphere gave excellent opportunities for observation. In the matter of map making, the basis for an understanding of distribution finds its foundation in a knowledge of latitude and longitude. Therefore the geographer is indebted to the mathematical astronomer for the graphical representation of the earth. We can not understand the make up of the earth, the so-called "mineral kingdom," unless we deal with chemical materials. It is the laws of physics which enable us to theorize about and understand the workings of many geologic processes, as mountain formation and volcanic activity. It is indeed obvious that physical geography rests in an intimate relation with these sciences; so much so, that certain phases of that study are termed geophysics and geochemistry.

In botanical fields such questions as these "What determines the flora of the steppes?" "Why are some regions treeless and others grassy?" "How is it that the same alpine plants are found on widely separated mountains and not in the intermediate area?" "Why is the cactus provided with water storage organs?" "What are xerophytes, hydrophytes, mesophytes?" These and infinitely many more questions of a similar nature will find their adequate answers only when based upon a knowledge of physical conditions and climatic facts.

In the study of animal life we do not find so direct a dependence upon geographic conditions as in that of plants, just as among men of to-day the dependence upon immediate environment is less marked than in the life of their primitive ancestors, largely because of the "power of locomotion." However, the mere existence of zoogeographical maps shows that there is, nevertheless, a distinct and important relationship. One finds that species and their distribution are determined largely by food, climate and physical conditions. The mountain goat, the camel of the desert, the river beaver, the wading and swimming birds, the antelope of the plains, the apes of the jungle, the reindeer and polar bear in the arctic, the coral in the warm seas—many of their adaptations are determined by the geography of their homes.

In the study of the highest of animals the same influence is of remarkable importance in the shaping of his character and habits. Why does the African have as occupations, hunting, fishing and modest kinds

of agriculture? Why are the Negroids more advanced in culture than the true blacks? Why are the Thibetans pastoral? Why did the Incas represent a superior American type? How have peoples been influenced by the presence of a great river, a vast desert, a yielding mountain, a tundra waste? These questions, and many others relating to man's habits and culture, occupations and history, are intimately associated with geographical considerations.

In the history of medicine and hygiene one can trace, likewise, an interesting connection. Where do bacteria flourish? Where have developed the malignant fevers? The amount of ozone in the air, the amount of moisture, which lessens or raises the rate of evaporation of the body, thus tending to raise or lower the temperature of the blood, is a relevant consideration here. In hot climates bodily activities are lessened because less internal heat is required to maintain the blood at its normal temperature; tissue changes go on at a much slower rate, and these include processes of nutrition. The amount of perspiration, the color of the blood, the color of the skin, have geographical significance, because of the varying action of the liver in various localities.

The relationship of geography to thought can, likewise, be but briefly touched upon here. Psychology, according to James, "deals with states of consciousness as such"—with all states of consciousness—that of the child, the criminal, the lover, the workman, the poet; and in so far as geographical conditions may affect a state of consciousness, to that extent does the geographical factor have a bearing upon psychology. And indeed this factor is quite as important in certain respects as other factors of heredity, physiological constitution, immediate environment. James says: "Mental facts can not be studied apart from the physical environment of which they are cognizant." Strachey writes: "By the influence and study of external nature are found and developed man's emotional, intellectual and moral faculties. The emotions created in the mind by the vast extent of the ocean, the ever-moving surface, the broken outlines of land and sea, the richness and luxuriance of the vegetable clothing of the earth, the never-ceasing transformation of the clouds as they float overhead, the large serenity of nature at rest, and the overwhelming violence of her convulsions, are, even though not consciously, the source of many psychological attitudes." Indeed, the states of consciousness of peoples may be viewed, in a way, according to geographical conditions. At the sea, mountain dwellers, peoples living in fertile valleys, people inhabiting regions of volcanic or atmospheric disturbances, the desert tribes, or peoples on beautifully luxurious lands—we find their psychological attitudes individually stamped. If typical individuals from such localities were examined, what a range we should find in imagination, optimism, attention, superstition, emotion, habit—

all provinces of psychology! Occupations affect mental states to a great extent, and these often depend upon geography. Health, often determined by drainage, swamps, ozone—how well do we know to what extent it can make or unmake our minds!

Philosophy, which may be briefly defined as an attempt at formulating the universe, utilizes the material results of all fields of knowledge and science, and, in so far as these are related to geography, in so far is philosophy also associated. For the names of philosophers who have been influenced by geographical problems and conditions, one has but to turn the pages of the history of geography, and see the names of Thales, Aristotle, Pythagoras, Ptolemy, Bacon, Ritter, Tyndall, Darwin, Comte. What can, and has, more radically shaped theories concerning the ultimate and the universe than the attempts at the solution of such problems as uniformitarianism, diastrophism and vulcanism?

Religions may not have had their *origins* in natural phenomena, yet the influence of these has often played a wonderful part. From the Himalayan austerity, the solitude of tropic forests, the unmastered floods of great rivers—from such tremendous natural phenomena came the Hindoo religion, a nature worship tinged with the melancholy of future oblivion. In Hindoo mythology the lofty mountains are invested with great sanctity and thousands of pilgrims journey year after year to the holy sources of the Ganges. From the cruel desert came the idea of Mohammedanism, of eternal bliss, an unending dream of sensuous delight attained by the faithful after the privations of a desert life. Ancient Jewish religion was much affected by the geographical factor. Where, too, did the puritans dwell and what was the type of their religion? And how has commerce, born of a geographic source, influenced the religions of men?

J. A. Symonds says: "In their early ignorance of cause, the Greek wondered at everything. When thunder terrified them they attributed their own nature to the phenomenon, and they conceived of Heaven as a vast body which gave notice of its anger by lightning and thunderings. Their sun was called a shepherd, in the early myths, and the clouds his sheep. It was easy for them to make a god of the sea—a husky-voiced and turbulent old man whose form none might clearly know because he changed so often and was so secret in his ways, who shook the earth in anger and had the white-maned billows of the deep for horses." All earliest religions at least *had* their nature worship. The rain made food grow; the sun gave warmth; the thunder-storms could put an end to a long drought. Then, there is a minor nature worship that deals with rivers and springs, with trees and groves, with rocks and stones. The spring was haunted by nymphs, the oak inhabited by a dryad. The Nile and the Ganges were holy. England is full of "sacred hills" which once received prayers and offerings. High places were hallowed in all lands.

In the fields of music, literature and art do we find the psychological attitude greatly influenced by geographical environment. Music's origin must be looked for in natural causes. The elements of all music exist around us, in the sighing of leaves, the gentle monotone of the winds, not less that in the roar of the ocean or the impressive tones of thunder. Earlier peoples imitated these sounds. And, where climatic conditions were good for the throat, singing qualities were developed. Where external conditions were not good for the throat there was a greater amount of inventing rude and noisy instruments. Brinkton says: "The use of noisy instruments recalled the voices of pealing thunder, the mad rushing waters and the wailing of the winds." Early music went hand in hand with the dance, which was, in turn, largely developed in warm climates and on fertile soils. The Esquimaux savage does not sing and dance as the tropical ones, nor does singing come from the people of the frozen tundra save of the poorest sort. Most Hebrew music was strangely harsh; many of their instruments, tabret, buggag, cymbal, pipe, shawn, chiefly wind and percussion instruments, meant *noise* with piercing effects. For, unsettled "dwellers in tents" as they were, this rough element was unavoidable, for, in moving about they came into contact with the rough elements of nature—storms, sea, winds. The Hebrews who were not "dwellers in tents" had, on the other hand, beautiful music—divine gratitude to Jehovah. The Romans had no music, because they were enormously successful commercially, because of their geography, and war and conquest were their first considerations. Something of the same is true of America to-day. Too anxious to utilize to the fullest extent her geographical wealth, she borrows music; chiefly from the negro. Folksongs, one of the truest types of music emanate from the geographically determined life of peoples. All nations had their songs to the soil, to the flock, to the soldiers' march through plain and mountain, had songs of the fisherman, the sower, the reaper. No doubt Russian music owes much of its melancholy and plaintiveness to the great mournful steppes. Why did the violin develop in Italy? Because it, of all instruments, resembles the human voice which was revealed to the Italians. The great German musical names, Beethoven, Mozart, Schubert, Haydn, Handel, Bach, come from *southern* Germany and were influenced by the singers of Italy.

Art, with civilization, seems to have arisen in the three great river basins of the Nile, Tigris, Euphrates, where the people had plenty of comfort and time to satisfy their desire for beauty. The amount of coarse, hard, massive rock available no doubt influenced the colossal architecture of Egypt. Chaldæa is a stoneless country, therefore its arts depended upon the nature of the clays. They, the Chaldæans, invented the potter's wheel—the beginning of a great field of art and industry—ceramics. Art of two dimensions, so to speak, painting, tapestry and

embroidery, has been probably more affected by geographic environment than any other forms. Commerce had a distinct influence here. The crusades brought the new world into contact with the east, and European manuscripts became beautifully illumined after oriental style. Climate, here, too, exerts no little influence. In dry, clear countries the people can see great distances, everything stands out in bold relief, and paintings are apt to be very bright in color, quite different from the work in moist, foggy lands. The Japanese, Chinese and Hindoos possess a natural artistic skill probably greatly determined by their geographical wealth—gold, metal, precious stones and ivory, the silk-worm, and the many vegetable paints and dyes that could be made from the soils. The making of carpets and tapestries goes hand in hand with such climatic conditions as will produce wool and silk. The pearl carvings are most beautiful among people living near the warm waters of the Pacific and Indian oceans. There is a great predominence of yellow and red in Indian designs—because iron compounds are plentiful in the earth. The refinement of Greek detail would never have been possible without her fine marble quarries Indeed, climate and the prevailing materials in any country determine much the character of the finished building. The towers, minarets, fine tracery and carving of the cathedrals and churches of Europe owe their existence to a great extent to the use of soft limestone and caenstone. There are flat roofs in dry countries, pitched roofs where there is little rain, and steep ones in snowy regions.

In dealing with literature in this connection, people may shake their heads. If one attempts to trace the influence of sea, mountain, desert, river, seasons, climate, they might say "Of course. That is nature. Of course our literature reflects those things." But, if literature were permeated with expositions of and similes concerning the mechanics of solids and fluids, would it not be interesting at least to trace the relation between physics and literature? The first literary themes of peoples are always songs of the sea, the river, the night, the mountain. In the songs of Indian, American and African savages there is an endless maze of themes to the winds and erosive forces of nature. Many of our literary monuments are merely recitals of geographical exploration and discovery—from Ulysses to Gulliver. The seasons have been sung by Shelley and more others than there is space to name. All stories of *Wanderlust* are associated with the spring time. Literature of specific areas is definitely stamped. Italy, because of her geographic condition, has been a distinct influence not only upon her own writers, but upon all writers who have journey there—Bryon, Goethe, Shelley, Browning, Keats, Milton. The influence of the north—how absolutely can we trace it! Beowulf is a mirror, almost, of the grimness of the north. Fiona Macleod, Ibsen, are essentially of the north. Pick up *Brand*. Where else could it have been produced? The desert, the river, the sea, the mountain, have been inspirations of many literary efforts.

All this may seem as much a "mere rush of detail" as that spoken of as characteristic of the geography of our school-days; but the details are of a different nature—more vital and of more human interest. Though the field is, I grant, entirely too large to be covered in a brief paper, yet, to make of geography not merely a collection of bald facts, but a study most intimately associated with and related to the fields of human activity—commerce, industry, history, science, thought, music, literature and art—that is what I mean by a "philosophy of geography."

CHINESE MATHEMATICS

By Professor DAVID EUGENE SMITH

TEACHERS COLLEGE, COLUMBIA UNIVERSITY

NO one who is interested in China and in things Chinese, and no one to whom the evolution of thought appeals, can fail to appreciate the recent articles by Dr. Edmunds, the learned president of the Canton Christian College, upon science among the Chinese.[1] His extensive travels in all portions of the country, his own scientific attainments, his wide acquaintance with Chinese scholars, his connection with numerous scientific expeditions, and his official position at the head of one of the most progressive colleges in the country, all qualify him to speak as one having authority.

It is, however, quite natural that one whose tastes are not primarily in the line of mathematics should fail to do justice to the work of Chinese scholars in this field. It is true that this work was not of a high order, and yet it must be said that it ranked with that which was being done in other branches of science, and had not the relatively low standing that would be inferred from Dr. Edmund's statements. These statements are summarized in the following:

> The study of arithmetic has attracted attention among the Chinese from early times, and notices found in historical works indicate some treatises[2] extant even in the Han Dynasty (206 B.C.–A.D. 214), followed by a great number of general and particular works down to the Sung Dynasty (1020–1120 A.D.). The Hindu processes in algebra were known to Chinese mathematicians, but though studied even after intercourse between the countries had ceased, these branches made slow progress down to the end of the Ming Dynasty (A.D. 1368–1644).[3]

Now as a matter of fact there is a good deal known of the mathematics of China in the pre-Christian era, and in certain respects their algebra in the Middle Ages was much in advance of that of their European contemporaries. Furthermore, this algebra appears to have been indigenous to China. While Sanskrit was known there very early, and by about 800 A.D. was even taught in Japan (through the writings of the great scholar, Kōbō Daishi), there is nothing in the mathematics of either country that shows dependence upon any known works of Hindu scholars. On the contrary, it would seem that Brahmagupta, who

[1] THE POPULAR SCIENCE MONTHLY, Vol. LXXIX., p. 521; Vol. LXXX., p. 22.

[2] Misprinted "treaties" in the original.

[3] Vol. LXXIX., p. 527. Substantially repeated in Vol. LXXX., p. 30.

wrote in Ujjain in the seventh century, was indebted for at least one of his problems to the great Chinese classic, the Chiu-chang Suan-shu.

Of the scholars whose contributions to mathematics were noteworthy, it will suffice to mention only a few, although it should be stated that these are the greatest of their respective periods so far as we now know.

No one knows how far back the Chow-pi goes. It purports to be a dialogue between Chow Kung and Kao (or Shang Kao) and to have been written c. 1100 B.C. Wylie[4] translates part of it, and shows that it contains a reference to the Pythagorean proposition and to a primitive trigonometry. It has long been known that the discovery of Pythagoras was the proof and not merely the fact, for the latter is mentioned in Egyptian writings before his time, and in Hindu works that probably antedated him, so that it is not surprising to find it in China.

Chang T'sang, who died in 152 B.C., restored the Chiu-chang Suan-shu, or Arithmetical Rules in Nine Sections, for the antiquity of which, in its original form, great claims are made.[5]

From the standpoint of mathematics the most interesting features of this work are the use of negative numbers, the trigonometry of the right triangle, and the fang-ch'êng process. The last named constituted one of the nine sections and concerned the solution of simultaneous linear equations. This would hardly be worth mentioning except for three reasons: (1) We have nothing of this kind in the algebra of Europe as early as this; (2) from this method of the Chinese came, by direct descent, the early Japanese method that led by obvious steps to the invention of determinants by Seki before the idea occurred to Leibnitz;[6] (3) the method for the extraction of roots led Ch'in Chiu-shao, in 1247, to anticipate Horner's method, as will presently be shown.

Sun-tsŭ, whose date is unknown, but who probably lived in the third century of the Christian era, wrote a work on arithmetic in which he set forth the process known as t'ai-yen ch'iu-yi-shu, a form of indeterminate analysis that was afterwards employed with much success. It

[4] "Chinese Researches," Shanghai, 1897, Part III., p. 163.

[5] From the preface of the edition by Liu Hui (third century A.D.) we have this statement: "After the terrible Ching had burned the books, the classics and (works on) arts were dispersed and lost. Later, in the Han Dynasty, the Duke of Pei-ping, Chang T'sang, and also Ken Shou-Ch'ang (Ching Ch'ou–ch'ang) a Commissary agent, were well known because of their talents in (the domain of) number. T'sang and this other, because of the incompleteness of the ancient writings, revised (by adding to and taking from) the work. So did each claim. Upon comparing the contents their works were seen to differ from the original, but the subject matter is much alike."

The origin of the work is often asserted to go back to c. 2650 B.C.

[6] See T. Hayashi, "The Fukudai and Determinants in Japanese Mathematics," in the *Tōkyō Sugaku-Buturigakkwai Kizi,* Vol. V. (2), p. 254.

is this general form to which we give the name of Diophantine analysis, although Diophantus probably lived after Sun-tsŭ. One of his problems is as follows: "Find a number which when divided by 3 leaves a remainder of 2; when divided by 5 leaves a remainder of 3; and when divided by 7 leaves a remainder of 2." At a considerably later date such problems were common in Europe, and were evidently imported from the East.

Tsu Ch'ung-chih (428–499)[7] certainly deserves mention if any standing is to be accorded to Metius in the history of mathematics, since he discovered the latter's value of π some twelve centuries before it saw light in Europe. About two hundred years before him Liu Hui[8] (in 263 A.D.) had given the value $^{157}\!/_{50}$ ($=3.14$), and Wang Fan had suggested $^{142}\!/_{45}$ ($=3.1555\ldots$). But Tsu Ch'ung-chih, working from inscribed and circumscribed polygons exactly as Archimedes had done, showed that the ratio lay between 3.1415926 and 3.1415927. As limits he fixed upon $^{22}\!/_{7}$, the Archimedes superior limit, and $^{355}\!/_{113}$, the value found by Metius. How Tsu came upon these limits we do not know, since his work (the Chui-shu) is lost, but it is possible, as Wei[9] asserts, that he knew something of infinite series.

Wang Hs'iao-t'ung, who lived in the first part of the seventh century, wrote the Ch'i-ku Suan-ching, in which appeared an approximate method of solving a numerical cubic equation. At a later period this would not be significant, but when we bear in mind that this is two centuries before Al Khowārazmi (c. 825) wrote the first book bearing the title "Algebra," and some three hundred years before Alkhazin (c. 950) and Al Mohani were working on this simple cubic, it is interesting.

The golden era of native Chinese algebra was the thirteenth century, made notable by reason of the works of three men living in widely different parts of the empire. Of these, one was Ch'in Chiu-shao,[10] who wrote the Su-shu Chiu-chang in 1247. This must always stand out in the history of mathematics as a noteworthy contribution, for here we find the detailed solution of a numerical higher equation by the method rediscovered by Horner in 1819, the only essential difference being in the numerals employed. As already stated, Ch'in merely elaborated the process for finding the square and cube roots as laid down in the Chiu-chang Suan-shu some fourteen centuries earlier, and this raises the question, How did Leonardo Fibonacci of Pisa solve the numerical equation of which he gives the root to such a high degree of approximation? He wrote his work in 1202. Did he have some

[7] Not the sixth century, as Cantor states.

[8] Lew-hwuy.

[9] The Chinese historian of mathematics.

[10] Tsin Kiū-tschau, as Cantor has it.

hidden knowledge that had come from the Far East—some work upon which he as well as Ch'in Chiu-shao was able to build? It is one of the many questions in the history of mathematics that still remain unanswered. That the problem of the couriers, commonly attributed to the Italians, is also found in Ch'in's work, is likewise significant.

Li Yeh[11] (1178–1265) composed two algebras, the T'sê yüan Haiching (1248) and the Yi-ku Yen-tuan (1259). Curiously enough, both works relate solely to the method of stating equations from the problems proposed, and not to the method of solving these equations. He also applied algebra to trigonometry, however, thus anticipating in some measure the European analytic treatment.

Chu Shih-chieh, living also in the thirteenth century, wrote his Suan-hsiao Chi-mêng in 1299, and his Szŭ-yüan Yü-chien in 1303. In these two works the native algebra of the Chinese may be said to have culminated, the methods of his immediate predecessors being here brought to a high degree of perfection. In the latter treatise the so-called Pascal triangle is found, and Chu mentions it as an ancient device that was used in solving higher equations. This was some three hundred and fifty years before Pascal (1653) wrote upon the triangle.[12]

Kuo Shou-ching (1231–1316) introduced the study of the spherical triangle into China, although for astronomical purposes only. His work was apparently influenced by the Arabs, and so can hardly be called a native Chinese production.

No mention has been made of a work known as the Wu tsao,[13] written in the fifth century; of the Suan-ching, one of the great treatises on Chinese arithmetic; nor of Chin Lwan who wrote the Wu-king-suan-shu in the seventh century; nor of his probable contemporary, Chang Kew-kien, who also wrote a Suan-ching, nor of several other well-known writers, because these men contributed nothing to the science of mathematics. They were makers of text-books with a genius for exposition, but without a genius for mathematical discovery.

Enough has been stated, however, to show that the Chinese probably found out for themselves certain truths of geometry, and among these the Pythagorean theorem; that they early developed a plane trigonometry; that they did good work in approximating the value of π; that they possibly did some original work in infinite series; and that they certainly led the world at one time in algebra. It is probable that we shall soon see the publications of translations of the writings of the early mathematicians of China, or at least such a study of their works as Endō, Hayashi, Kikuchi, Fujisawa and Mikami have made of the native Japanese treatises. When this comes to pass we may possibly

[11] Li Yay, as Cantor has it.

[12] It seems first to have appeared in print in a work by Apianus, 1527.

[13] Five sections.

be able to appreciate the contributions of Chinese scholars even more highly.[14]

[14] The writer is indebted to various works upon Chinese science, and to the help of a number of scholars. It will possibly assist some reader if a few of these authorities are mentioned: A. Wylie, ''Chinese Researches,'' Shanghai, 1897, Pt. III., p. 159; M. Courant, ''Bibliographie Coréene,'' Paris, 1896, Vol. III., p. 2; J. Legge, ''Chinese Classics,'' 2d ed., Vol. I., p. 4; H. Cordier, ''Bibliotheca Sinica,'' Paris, 1905–6, Vol. II., cols. 1372, seq.; A. Vissière, ''Recherches sur l'abaque chinois,'' in the *Bulletin de Géographie,* Paris, 1892; S. W. Williams, ''The Middle Kingdom,'' edition of 1895, Vol. I., Chap. XI.; A. Wylie, ''The Mongol Astronomical Instruments in Peking,'' in Vol. II. of the ''Travaux de la 3e. session du Congrès internat. d. Orientalistes''; A. Wylie, ''Jottings of the Science of Chinese Arithmetic,'' in the *North China Herald* for 1852; M. L. Am. Sédillot, ''De l'astronomie et des mathématiques chez les Chinos,'' in the Boncompagni *Bulletino,* Vol. I., p. 161; Y. Mikami, ''Mathematical Papers from the Far East,'' Leipzig, 1910, p. 1; Y. Mikami, ''A Remark on the Chinese Mathematics in Cantor's Geschichte der Mathematik,'' in the *Archiv der Mathematik und Physik,* Bd. XV. (3), S. 68, and Bd. XVIII. (3), S. 209. There are also the various histories of mathematics, including those of Montucla (2d ed., tome I., p. 451) and Cantor (Bd. I.). The writer is also indebted to Dr. W. A. P. Martin and to Mr. Mikami for personal communications relating to the subject. He is also largely indebted to his pupil, Professor T. H. Chen, of Peking, for numerous translations, including extracts from the Chinese historian of mathematics, Mei Wuh-ngan, and a translation of the entire T'sê yüan Hai-ching (1248) of Li Yeh.

THE PRACTICAL BASIS FOR REPUBLICAN INSTITUTIONS FOR CHINA

By GUSTAVUS OHLINGER, A.B., LL.B.
TOLEDO, OHIO

A RECENT issue of a Chinese daily published in Shanghai records this incident: The venerable teacher Chang, a man well known and respected in his community, was stricken with a mortal disease. Three days before his death he requested his eldest son to shear off his queue, explaining that "though he had worn this badge of servitude to the Manchu usurpers for over three score years, now that the day of freedom was at hand, he desired to appear in the other world, not as a slave, but as a free son of Han." The native press, which is almost entirely revolutionary in its sympathies, refers to the contending armies as the "patriots of Han" and the "Manchu slaves." The revolutionary manifestoes run in the name of the "People of Han," and some bear date from the "founding of the Han Dynasty."

These references all hark back to the golden age of Chinese history, when the house of Han, of pure Chinese blood, wielded the vermilion pencil in the ancient capital of Nankin. Their pertinency in the present struggle for constitutional liberty is further emphasized by the fact that under this dynasty the Chinese received their first charter of rights. In 206 B.C. the emperor Han Kao Ti, as wise, far-seeing and gracious as our own King John was stubborn and recalcitrant, made what is known in Chinese chronicles as "the Tripartite Bargain with the Elders of the People." This oriental Magna Charta is summarized in the terse Chinese ideographs as follows: "(1) Death for homicide; (2) compensation and imprisonment for wounds and robbery; (3) all else left to the people."

From that day to this the "bargain," particularly the "all else left to the people," has epitomized the Chinese conception of the functions of government. There have been many codifications of the laws of the empire, nearly every dynasty having signalized its accession by a new code. One feature, however, characterizes all this legislation—the entire body of the law is criminal. What concerns the people in their business and social relations has, in the words of the charter, been left to the people. Search the "Ta Tsing Leu Lee," or the "General Laws of the Imperial Dynasty of Tsing," as the present code is known, and there will be found a most careful classification of crimes, one, moreover, which faithfully reflects the ethical standards of the people. In

fact, much of it reads like a paraphrase into legal terms of the moral teachings of Confucius. To this is added a minute gradation of punishments. But in all the thirty-six volumes in which the code is usually published there is hardly a reference to contracts, and no mention whatever of negotiable instruments, partnerships, or to any of the other branches of civil law.

It is in this broad field of private rights and liabilities that the genius of the people for organization and regulation displays itself. Aside from literary pursuits, the absorbing interest of the Chinese is trade, and in this department they brook no interference from governments or authorities. Commerce is closely organized. In a large commercial center the traders in every staple have their association, the visible evidences of which are the large, substantial guildhalls. In Shanghai, for instance, will be found a piece-goods guild, an opium guild, a silk guild, a bankers' guild and numerous others of lesser importance—in fact, no class in China seems to be so ignorant or so poor as to be wanting in some organization for the protection of its members. There is even a beggars' guild.

The guilds are something more than we might infer from the term. They have an overshadowing prestige. Some years ago the viceroy of one of the coast provinces attempted to levy an additional impost on salt. The merchants protested. The viceroy was obdurate. Not a catty was sold until the distress was such that he was compelled to yield, and shortly after memorialized the throne to be relieved of his official duties "in order that he might visit his parents." Negotiable paper has been in use in China for many centuries. The well-defined usage on this subject is the outgrowth of the regulations of the bankers' guild. More recently, the law of insurance has been provided by the underwriters' guild, that of transportation by the shippers' guild, and so on. In fact, it has been said by an authority on Chinese business customs that if the by-laws of all the various guilds could be gathered together, the collection would constitute not only a logical, consistent commercial code, but one far better adapted to its purpose than any that could be produced by the ordinary processes of legislation.

Commercial disputes very rarely come before any court for adjudication. Between members of the same guild such matters are decided promptly, finally and satisfactorily by the guild itself. Differences between members of independent guilds are referred either to a joint committee, or to a third body for arbitration. If a point involving commercial usage comes before a magistrate it is usual for him to call for a ruling from the proper guild.

The aloofness of the government is further illustrated by the laws covering marriage and divorce. The code defines with exactitude the relationships in which marriage is unlawful, but no such thing as a

license or a public ceremony is required. It is left to the individual to make his matrimonial choice within the limits provided by law, and then to celebrate his nupitals in his own way. Should he mistake his rights and marry within one of the prohibited degrees he is subject to punishment. The same attitude is maintained towards divorce. The code specifies the grounds for such a separation, enumerating besides those recognized by us, such delinquencies as "talkativeness," "envious and suspicious temper," "disregard of the husband's parents." Upon any of these the husband may give his wife a bill of divorce. Should he, however, perchance misjudge his own case, he is subject to eighty blows of the bamboo.

An interesting feature of the Chinese ethical system which the code brings into prominence is the idea of mutual responsibility. It is provided that "when the parties to an offense are members of one family, the senior and chief member of that family shall alone be punishable; but if he be upwards of eighty years of age, or totally disabled by his infirmities, the punishment shall fall upon the next in succession." By virtue of this principle, the burden of criminal responsibility has been known to descend from father to son for generations while a litigation was taking its leisurely way through the courts to the Board of Punishments in Peking, and finally to the Emperor, until in the end the penalty fell upon some person born long after the event. Of the same character is the mutual responsibility of persons residing in the same neighborhood. A typical case is where a parricide having been committed, all the houses in the vicinity are demolished, the theory being that the residents have been culpable in failing to exert a better moral influence over the criminal.

A feature of Chinese society which makes for democracy is the almost total absence of such a thing as a hereditary nobility. For over two thousand years the descendants of Confucius have been honored with the title of "Dukes of Kung," and in the same manner the descendants of the famous sea-fighter Koxinga have been distinguished with a hereditary title. But with these exceptions, and with the exception of the imperial family, the only aristocracy recognized generally in China is based on learning, and this is open to the humblest and most powerful upon like terms. The tourist in the provincial capitals is usually shown the examination halls—rows upon rows of tile-roofed sheds divided into cells not more than six feet square. Here every three years the candidates for literary degrees gather from all parts of the province.

Until recently the Chinese classics have been the subject of all examinations. The chancellors selected at random a phrase from the works of some ancient moralist which the students were required to expand into an essay framed on the stilted canons of Chinese literary

style. In 1898 the late Emperor, Kuang Hsu, realizing the futility of such exercises, abolished the "eight-legged examination essay" and substituted modern sciences. This measure found its reaction in the Boxer uprising two years later. The disasters of the frenzy, however, convinced all of the inadequacy of ancient literary lore, and the result is seen in the marvellous intellectual awakening which followed it. Western learning was snatched up with avidity; students were sent abroad; scientific works were translated and published; modern methods were introduced into government schools, whence they are now invading the examination halls.

From the literary class recruited through the examination system the positions in the government are filled. The man with a degree at once becomes one of the "headmen" of his village, and usually, by common consent, holds the office of *ti-pao,* which corresponds to that of our justice of the peace and notary combined. He authenticates deeds, settles disputes among his neighbors, and acts as their spokesman and representative in all that concerns the higher officials. Or he can attach himself to some official in a clerical capacity, his subsequent rise to the highest positions in the government being dependent upon his industry, diplomacy and political acumen. Such statesmen as Li Hung Chang, Chang Chih Tung, and the present Yuan Shih K'ai, rose from humble stations.

To the advocate of a republican China, the examination system is the strongest argument that can be advanced for his cause. It so intimately reveals the Chinese character. The man who is successful in an examination covers not only himself, but his family and community with glory. The Chinaman is not attracted by the demagogue, but he has a profound respect for the opinions of those who by assiduous toil and severe test have won their way to intellectual honors. He has for centuries been accustomed to look upon these men as the logical repositories of political power.

The provincial assemblies, which have been held in the last two years, proved a revelation to all observers. The discussions were intelligent and revealed a sincere purpose on the part of the members to promote the general welfare. They have proved that the hopes of the revolutionary leaders are far from chimerical. The basis for republican institutions in China is broader and safer than in many other countries that enjoy self-government. The people are by nature and habit industrious, peace-loving and accustomed to self-restraint. In the aggregate of relations and transactions which make up social and commercial life they have suffered less interference than the average American citizen. The great mass of rules governing the relations of men they have formulated themselves, and they have learned, moreover, the sobering lesson of submission to law as the best guaranty of the rights of all.

A PROGRAM OF RADICAL DEMOCRACY

By J. McKEEN CATTELL

THERE is advance towards radical democracy in every nation. In the United States the two political parties have made some progress in recent years in answer to the demands of the people; but this slow and halting movement, falling behind that of Great Britain, should be hastened, either by the formation of a new political party or of a radical section within one of the existing parties. The socialist party might serve as a center of union, if questions concerning the production of wealth and the limitation of individualism can be subordinated to social welfare. The best solution, however, of the existing political situation would probably be the maintenance of the two historic parties, the republican party being frankly devoted to rule by the privileged classes under the leadership of men such as Mr. Roosevelt, Mr. Taft and Mr. Hughes; the democratic party to control by the people with as little individual domination as may be. Twenty reforms in the direction of radical democracy are here indicated. Some of them may appear to be utopian and doctrinaire, but there is not one of them toward which progress has not been made in recent years, not one of them toward which further progress will not be made in the near future.

1. *Universal suffrage, the votes of children being cast by their parents.* The bearing and the rearing of children are so much more important than any other work that the right to vote is in comparison insignificant; but voting would in no way disqualify women for their greater service, and this surely should not disqualify them from voting. Women have long been goddesses, queens, prostitutes and slaves; it is clearly time that they should have exactly the same political, legal and economic rights as men. Women are on the whole more sympathetic, patient, personal, emotional, illogical than men. These traits would probably improve political conditions; but this is almost irrelevant. Universal suffrage is simply the presupposition of democracy. Children are also human beings, and their votes should be cast by their parents. This would give the correct distribution of political power and the basis for a complete political democracy. The substitution of the rights of children for the privileges of property is the greatest advance that can be made by society. The woman or man who has children is that much more of a woman or man and should vote accordingly.

2. *Personal liberty and local government.* The liberty of the individual should be limited only when it interferes with the liberty or the rights of others. The man who has smallpox must be isolated; one who mistreats his children must be imprisoned; the owner of an automobile, the upkeep of which costs more than the support of an average family, should be taxed; because each of them would otherwise interfere with the welfare of others. But legislation to suppress unobtrusive vice, to keep people married who want to separate, to prevent polygamy, and the like, is of doubtful value. The national congress should not do what state legislatures can do equally well, or the state legislature interfere with local government. The inequality and artificial boundaries of the states, the disastrous growth of cities, the heterogeneous and changing population, are among the conditions which make local government difficult. But the nation should not lord it over the states, the state over the county or city, the county or city over its local units, these over the group or family, the group or family over the individual.

3. *The abolition or the limitation of the powers of the constitution of the United States, of the president, of the senate and of the supreme court. Similar limitations in state governments.* The national government being historically a federation of states may need some constitution, but it does not need much of one or one very much. It would be entirely safe for the congress to decide what the nation shall do and what shall be left to the separate states. Great Britain is better off without a written constitution. The scheme of checks and balances is wrong in theory and bad in practise. Men will nearly always rise to the level of the responsibility put on them. The existing lack of responsibility demoralizes the legislature; placing responsibility on the individual autocrat makes, as a rule, a good autocrat; but that is not what democracy wants. The president should be only the executive officer of the congress. The senate is a superfluous nuisance. A supreme court may be needed to decide what the congress intended when it enacted a law, but it is not there to play with the meaning of words or to interfere with legislation. Every outworn constitution and law, every perpetual franchise and charter, should be scrapped. The dead can not be permitted to rule the living.

4. *Government and all its functions to be executed by those most fit, selected by and responsible to the people.* Political democracy does not mean government by the uninformed, but by those best able to serve the people. Delegated and expert government is necessary; it is clearly impossible for the people to consider all the minor measures that must be enacted and all the minor officers that must be selected. The proper condition seems to be for those of a neighborhood to select the men in whom they have from personal acquaintance the most confidence, these

to select a representative to meet with representatives of other neighborhoods for the county or state, these representatives to select the national officers. But this scheme has broken down under the party system and the control which can be exerted by professional politicians and selfish interests. At present representative government has partly collapsed, but the demands of the people will soon be met. In the meanwhile direct nominations, the initiative, the referendum and the recall may be of use. But direct nominations favor notoriety and wealth. The referendum is a conservative rather than a radical measure; it can, however, be used to advantage as an educational method when all are concerned and interested. A commission should be more competent to select a health officer than a plebiscite vote, though it may be that the people would be more likely to be guided by expert opinion than is a temporary autocrat, such as Governor Dix. Great progress has been made in appointments for fitness and in civil service rules. The present unrest and dissatisfaction is not due to worse selections, but to higher standards. Our political organization and our politicians have advanced more slowly than the intelligence and the moral sense of the community.

5. *The payment of all national, state, county and municipal debts. Taxation discouraging private debts.* Freedom from debt is the first principle of personal and domestic economy. It is extraordinary that it should be so completely neglected in the case of public debts. If the socialist party wants municipalities and the state to own the tools of production, the first thing to do is to let them own themselves. Debts are the principal hold of the kleptocratic classes on the community, giving us our system of paper wealth by means of which a small class taxes the people. Temporary war debts can be understood, though nothing would conduce more to peace than the payment of the cost of war as it proceeds. Debts for exceptional public improvements are proper, but they should be paid within a fixed period. Contrary to existing practise, bonds should be taxed rather than stocks. The taxing of evidences of debt would limit borrowing and would return to the people part of the interest fund. The rich would be compelled to invest their money in productive enterprises, where it would be of use and would take risks, leading to its wider distribution.

6. *A national progressive tax on inheritances and incomes as large as can be collected. A progressive tax on corporations. A heavy tax on expenditures involving waste and luxury.* Inheritances and incomes should be taxed by the nation to prevent dodging if the taxes are local. No tax is good, but an inheritance tax is the least objectionable of all taxes. It taxes the dead or at all events those who have not had the property; it is easily and truly collected; it tends to the distribution of wealth. It should be at least half of large fortunes, and larger when

there are no children, or but one or two. An income tax promotes lying, but it should be adopted, and the sworn statements of all incomes and expenditures beyond the average should be made public. No one deserves more than, say, four times the average income. A man's services may be worth more than that, but they are made possible by the organization of society. A progressive tax averaging fifty per cent. on incomes above $5,000 would be desirable, if it could be collected. Every one who spends much more than the average should be placed under the supervision of the state. The connotation of stealing and robbery has been extended beyond force, but it must be further extended. The tax on corporations is the most excellent and radical measure passed by a recent congress; credit for this should be given to President Taft. In so far as large corporations are undesirable, they should be taxed progressively. The remaining income required by the national government should be from import and excise taxes on products the use of which involves injury, luxury and waste.

7. *A local and state progressive tax on real estate and tangible personal property.* State and local taxes should be on real estate and tangible personal property, situated where the receipts from the taxes are used. It is not clear that the increment of value on land belongs to the public more than the increment of value on personal property, but a transfer tax on real estate, based partly on the increment of value, can be conveniently collected and would discourage speculative holding. There should also be a large transfer tax on stocks and bonds, the increment of value being taken into consideration. A progressive tax on dwellings is the most useful of local taxes. A house or tenement, the rental value of which or of whose apartments is under $150 a year, especially if owned by the occupants, might be exempt, while a million-dollar dwelling might be taxed a hundred thousand dollars a year. Dwellings represent pretty accurately the annual expenditures, and a progressive tax is the most convenient way of taxing these. There should be a high progressive tax on tangible personal property that is not the tools of production—on expensive furnishings, pleasure automobiles and the like. Owners might be allowed to place their own valuation on real estate and personal property, the state or any individual being permitted to purchase it at twenty per cent. advance, the property being redeemable by the original owner on payment of this margin.

8. *The conversion of the army into local police forces and corps for engineering work and other improvements. The conversion of the navy into a merchant marine.* We should have the best army for defense and improved police forces if all local police were soldiers, one twelfth of their wages being paid by the nation and one month annually being spent in camps and drills. Idling in barracks is a method for the

promotion of war, drunkenness and disease. The engineering corps, the health service and the commissiariat are the most important factors in modern warfare. Engineers, health officers, inspectors of food and others employed by the nation, the states and the municipalities should be at the same time officers in the army and those under them enlisted men. A well-organized and efficient army for defense would thus be maintained at comparatively small expense and be an institution for education instead of for demoralization. The navy should be converted into a merchant marine, carrying a postal, express, freight and passenger service to every port in the world. At the cost of an idle navy five to ten times as many ships and men could be maintained and employed in useful work. In case of war swift ships and experienced men would win over dreadnoughts. Shipyards and factories for armaments and ammunition should be owned by the nation and manned by officers and enlisted men. The army and the navy can be made self-supporting nearly as easily as the postoffice. Fortunately they may be regarded as temporary institutions.

9. *Limitation of foreign treaties and representatives. No interference with foreign nations, except for humanitarian reasons. The submission of all international questions to arbitration.* We are warned against entangling alliances; all treaties are such to a certain extent, and in most cases are at present useless and dangerous, though international courts and agreements may in the future become desirable. Let us be just and generous to all nations and to all foreigners, and trust them to be the same to us. If they are not, those who see fit to deal with them should take the risks. Missionaries, traders and travelers should be subject to the laws and ways of the lands to which they go. Secret diplomacy has no place in a democracy; the social snobbery of an ambassador is disgusting; his political office is made useless by the cable. Arbitration treaties are unnecessary; but we should be ready to submit all questions to arbitration. There should be no interference with foreign affairs, except for clear humanitarian reasons, approved by neutral and disinterested nations. We shall be better off if South America is peopled by Germans and Russians as well as by Spaniards, Portuguese and Indians. War is avoided by delay. It should not be possible for the president to involve the nation in war, and no war except for defense should be undertaken before the question has been submitted to a plebiscite vote and carried by a majority exceeding one half of the population.

10. *Colonies and dependencies to be held only for the benefit of the peoples concerned and with their consent.* The vigorous and prolific races will supplant those which are decadent; but wars of conquest are now equally injurious to the conqueror and to the conquered. In the past it was necessary for an expanding population to subdue savage

races and sparsely populated regions, but with the exception of Africa such conditions no longer obtain. Races must work out their own destiny. India can not be ruled indefinitely for the support of the younger sons of the upper classes of England. Conditions have been inherited from a barbarous past, and we must make the best of them. But hereafter no race and no section of a nation should be held in subjugation by force, except for humanitarian reasons, which appear sufficient to neutral nations. Fortunately our own complications are practically limited to the Philippines and are not insoluble. Political conditions and social relations should be independent of race and color.

11. *Gradual reduction of the existing tariff.* The protective tariff has been one of our most disastrous adventures; the present opposition to it is a gratifying sign of national health. The tariff has not only caused boundless political corruption and waste of economic resources, but has forced people from a healthy life in the country into the cities, the manufactories and the mines, and has supplanted our native population with immigrants. It is largely responsible for inequality of wealth and industrial slavery. To meddle with the schedules of the tariff will cause further corruption and industrial disorder. It should be abolished gradually by a five or ten per cent. reduction annually on all schedules. Desirable import taxes can be separately imposed.

12. *The government to regulate the value of money, but not to engage in borrowing or lending.* If any one supposes the first part of this proposition to be due to Mr. Bryan, he is referred to the constitution of the United States. Mr. Bryan is essentially conservative, as are the people; but in his sympathies at least he is the best leader for a democracy that the country has had since Lincoln. In the bimetallic campaign he was not wrong in his aims, but only in his calculations. The present increase in prices—the cost of living is another matter—is in the main due to the depreciation of the value of gold, and is evidence of the inadequacy of a monometallic standard. The net result of this depreciation may not be bad, as it decreases the wealth of the passively exploiting classes, though it increases the wealth of the actively predatory classes and is unjust to those living on wages and salaries. But an unstable monetary standard is a bad business. The nation should fix a standard of value, based on the more important products of the country, and be prepared to redeem its paper currency in these products. It would not of course need to redeem it; the property of the nation is ample physical security. We have in fact a paper currency—checks and drafts being its most important part—but we need a fixed standard of value, first national and then international. A national bank is as objectionable as are the other activities of the author of the scheme. Postal savings may be of use as a temporary piece of paternalism, but should not be permanent. The banks, the bankers,

Wall Street and the money power should be controlled by progressive taxation.

13. *Complete reform of the courts.* Neither Mr. Taft nor Mr. Roosevelt is a radical or a democrat, though both to a certain extent—the latter increasingly—have followed the lead of the people. Mr. Taft is called a conservative and is unpopular because he regards the courts as sacrosanct; Mr. Roosevelt is called a radical and is popular because he attacks them. This is a healthy symptom. The injustice of courts established to promote justice is monstrous; their favoritism of the rich is intolerable. The domination of the legislature by the courts, their powers of injunction, imprisonment for contempt, convictions and acquittals on technicalities, appeals on technicalities, delays purchased by wealth and fines as an alternative to imprisonment, expert testimony, insanity pleas, false charges and pleas by district attorneys as well as by hired lawyers, all this must be swept away even at the risk of temporary disorder. The judges who decide that an employers' liability law passed by the legislature is not due process of law should be impeached. If needs be lawyers should be disqualified for a time from becoming judges or appearing at court. The domination of the lawyer and of his point of view in political life is most unfortunate.

14. *Free medical service and the promotion of health in every way that does not interfere with the freedom of the individual.* The conditions in medicine are not so bad as in law, but they are very bad. Great Britain is just now setting an example in medical reform which we should follow. It is better to promote health than to try to cure disease. All medical and surgical service should be free to those having less than the average income; no hospitals or clinics should be conducted as charities. Private and endowed philanthropy—except as a temporary expedient—is a public nuisance. The rich should be able to obtain the best medical and surgical services only in or from the hospitals, and should be charged in proportion to their means, the fee going to the hospital, not to the physician, who should have a fixed salary. The freedom of the individual, whether to carry on vivisection, to go without vaccination, or the like, should not be interfered with without good cause. Education, publicity, correct labeling and awards for damages are the best ways to prevent malpractise, fake medicines and adulterated foods. A billion dollars a year spent on the suppression of disease and the promotion of health would be a profitable investment, if men can be found to do the work.

15. *Old-age and disability pensions. Subsidies for all children.* People must be supported in old age and when disabled or submerged, and this should be done by the state as soon as we can manage it. It is not for the benefit of the state or the race, but is a reasonable demand on humanity. The necessities of life should be supplied to every one

and those who earn more should have more. Subsidies to children are for the benefit of the nation and the race as well as of the individual. Those we now give, such as free education, should be extended, until the cost of bearing, supporting and educating each child is borne equally by every one. The means for a healthy life should be provided for every child, and all possible opportunities for well-born and promising children. The care of children is dominant above every other privilege or duty of the individual and the state. Children are now supported by the resources of society, and with our existing wealth two or three times as much could and should be spent on each child. When the state attends to this the taxation will be large, but not unmanageable. The chairman of the committee on ways and means of the house of representatives estimates that a one-per-cent. tax on incomes above $5,000 will yield $60,000,000. The wealth wasted or saved from large incomes would consequently yield $200 for each child under sixteen. This sum will suffice, temporarily, if the locality provides schools, books, meals, medical service, etc.

14. *A maximum day's work of eight hours and a minimum wage of two dollars. No child labor, except what is of benefit to the child. A maximum annual income for an individual of $5,000; a maximum inheritance of $50,000.* Those who can't or won't work must be provided with the necessities of life. Those who can and will work should have not less than two dollars a day at the present purchasing power of money, and work must be provided for all. Eight hours is a day long enough for employment, but more can be accomplished by those who wish to devote more hours to useful work. Child labor, except for the benefit of the child, is absolutely intolerable. The average annual income of those who work is about $1,000 in Great Britain and in the United States. If idleness and waste can be eliminated it will be about $2,000, including women who care for the home. Under existing conditions, if the minimum wage is $600, an ample margin is allowed for competition, and every one can save money. The average wage being $1,000 there may be numerous individual incomes as large as $2,000 to $5,000, or $4,000 to $10,000 for a family. This is as large as any income should be, so long as the average income is $1,000. Each individual would in addition have by inheritance his home and his tools of production, his share of the wealth held by the nation, the state, the county, etc. But the inheritance of no individual should exceed $50,000. Incomes would be doubled by the suppression of idleness, mismanagement and waste and can be again doubled by the further advances of the applications of science. This fourfold increase of wealth will probably be available before any such partial equalization by taxation as is here proposed becomes feasible. Room can be left for competition and savings so long as such incentives are needed. We

may hope, however, that the game of life will become so interesting that it will not be necessary to play for stakes.

17. *The homes and tools of production to be owned by those who use them. The excess wealth to be owned by the locality, the state and the nation. The enterprises to be operated in the manner that gives the greatest economic efficiency and social welfare.* The homes should be owned by those who live in them—tenements and apartments, as well as city and country houses. Taxation of homes should be adjusted so that homes of average value are exempt or lightly taxed, while those of greater value are subject to a progressive tax, becoming prohibitive for palaces or estates. The tools of production should be owned by those who use them. The industrial slavery which has resulted from the passing from individual production to group production can be abolished only by group ownership. The group might be the community, but when possible it should be those who work in the factory, cultivate the farm, sail the ship, etc. The ownership and conduct of industries should be vested where the maximum economic efficiency and conditions most favorable to those who work will result. We all agree that the nation should own and manage the postoffice, the states the roads, the cities the water supply. The extension of state ownership and conduct is entirely a matter of economic efficiency and social welfare. The state should own large natural resources and enterprises, which by the nature of things are monopolies or can most advantageously be conducted as such. The nation should now conduct the telegraph and express service, probably the business of insurance; it or the states should own, but probably not conduct the railways. The states should own the mines and water power; the cities the means of transportation and illumination and the telephones; but at present they can probably be conducted most advantageously by private enterprise. Under existing conditions of human nature place must be given for competition and savings, and an official bureaucracy must be avoided.

18. *Education and research to be promoted to the limits permitted by the resources of the state.* It is the great triumph of our industrial democracy that it has supported free education as has no other nation. But we have still to learn what kind of education is of most worth and to extend it to every individual at every age. Together with the bearing and rearing of children, the greatest service to mankind is creation in science and art and their useful applications. In both cases production has been left to fundamental instincts; but these should be reinforced in all possible ways. Payment should be made for services to society no less than for services to individuals, for which only the present competitive system provides. We admit that research must be paid for by society; university chairs are given as rewards, research institutions are endowed, the government undertakes scientific work.

But we have by no means gone far enough. Abram H. Hewitt estimated that a single scientific advance—the Bessemer steel process—produces two billion dollars a year for the world. So much has not been spent on research in its whole history; but so much should be spent annually, as soon as men can be found or bred to do the work. Science has given us democracy by providing resources adequate to give each his share of education and of opportunity. Plato had to provide an aristocracy and slaves for his republic. Science by reducing to one fourth the manual work that each must do and by doubling the length of life has made democracy possible and has given us so much of it as we have. For the security and extension of political and social democracy, the advancement of science should be one of the principal concerns of a democratic government and of a democratic people.

19. *Equality of advantages to the young; equality of opportunity to all; no special privileges; individual liberty, except when this interferes with the liberty or welfare of others; so far as may be, to each all that he needs, from each all that he can give.* These are the ends which this program is intended to forward. They are the presuppositions of radical democracy and do not require argument or defense.

20. *The ends here stated to be reached only by gradual evolution and forwarded by conservative methods.* In a democracy certain individuals may be prophets or leaders, but we can not advance beyond or apart from the sentiments of the people. They as a whole are more likely to react correctly to the existing situation than any individual. It is proper and desirable that proposals shall be made and urged, however radical and revolutionary; it is equally desirable that laws shall be enacted only when they answer the demands of public opinion. A narrow majority should never enforce radical changes or unduly coerce a minority. Laws, measures and policies should as nearly as may be represent the average opinion after individuals have been counted and weighed. Revolutions are likely to keep on revolving and to be turned by cranks. There are occasions when a saturated solution may be crystallized by a shake; but we should trust to the slow processes of evolution, letting our leaders and our laws follow the moral and intellectual development of a democratic people. A government of laws is better than a government by men; but better than either is freedom, controlled by public opinion and common sense, by precedent and good will.

THE PROGRESS OF SCIENCE

CRAWFORD WILLIAMSON LONG AND THE USE OF ANESTHETICS IN SURGERY

On March 30, 1842, in the village of Jefferson, Georgia, Dr. Crawford W. Long administered ether to Mr. James Venable and, while he was completely anesthetized, removed a small tumor from the back of his neck. On the seventieth anniversary of the day, exercises in honor of Long were held in the Medical School of the University of Pennsylvania, from which he graduated in 1839. Addresses were made by Professor J. William White, of the University of Pennsylvania, and by Professor J. Chalmers Da Costa, of the Jefferson Medical College, and a bronze medallion designed by Professor R. Tait Mackenzie, of the University of Pennsylvania, was unveiled by one of the three daughters of Dr. Long who were present at the ceremony.

Thus somewhat late official recognition has been given at the University of Pennsylvania to one of the advances in the medical sciences, which make an epoch in their development. At the close of the second of an important series of lectures on medical research, published above, Professor Richard M. Pearce, of the University of Pennsylvania, calls attention to the new era in surgery introduced by the use of anesthetics. This not only saves immeasurable suffering, but it makes possible, and comparatively safe, operations that could not be undertaken if the patient could move and struggle. Professor Pearce does not attempt to assign credit for the discovery of anesthetics, though he properly attributes its introduction to the world to the administration of ether by Dr. W. T. G. Morton, a dentist, for an operation performed by Dr. J. C. Warren at the Massachusetts General Hospital on October 16, 1846.

Like scientific progress in many other directions, the use of anesthetics has had a long history, and we must speak of various advances rather than of a single discovery. The anesthetic effects of nepenthe, mandragora and hemp were known in antiquity, and it is said that surgical operations under them were performed in the time of Pliny, in China and in the middle ages. Sir Humphry Davy in 1800 announced the discovery of the anesthetic properties of nitrous oxide, and wrote, "it may probably be used with advantage in surgical operations." Ether had been known for centuries, and in the first part of the nineteenth century its vapor and nitrous oxide gas were used for spasmodic asthma and to relieve pain. They were also used for their intoxicating effects, and it was under such conditions that Long noted their anesthetic properties.

Somewhat more than two years after the operation by Long, Dr. Horace Wells, a dentist of Hartford, Conn., had a tooth extracted while rendered insensible by nitrous oxide, and two years later, as noted above, ether was used by Dr. Morton. Dr. Wells and Dr. Morton had been in partnership, and both had been pupils of Dr. C. T. Jackson, the distinguished chemist and geologist of Boston, who in 1841 had experimented with both nitrous oxide gas and with ether, using them for the relief of pain. Morton patented ether in 1846 under the name of letheon, and a bitter controversy followed, in which Jackson, Wells and Morton were involved. Wells became insane and committed suicide. Later Jackson also became insane. Morton died from apo-

BRONZE MEDALLION IN MEMORY OF CRAWFORD W. LONG.

plexy, it is said while enraged at the attempts made to deprive him of the credit of the discovery. Long took no part in these controversies, but in 1849 presented a statement to the Medical Society of Georgia, with affidavits in regard to the use of ether in 1842, followed by seven or eight surgical operations before Morton's success in introducing anesthetics everywhere. The question of priority is thus much involved, but it appears evident that Long first used ether for surgical purposes, though, as a country practitioner, he had no means of making public his discovery and perhaps did not fully realize its importance. It seems, at all events, that the use of anesthetics in surgery is one of the great advances in science which may fairly be attributed to the United States.

THE SCIENTIFIC PROGRAM OF THE AMERICAN PHILOSOPHICAL SOCIETY

THE American Philosophical Society, founded in Philadelphia by Franklin for the promotion of useful knowledge, is the oldest of our scientific societies and at the same time appears to be the most vigorous of those that cover the whole range of the sciences. The meeting held in Philadelphia at the end of April was quite notable for the number and value of the communications. They not only gave reports of important original investigations by the authors, but were in most cases presented in a manner comprehensible and interesting to those who are not specialists. It is of course impossible to give an abstract in two or three paragraphs of nearly

THE LATE JOHN BERNHARDT SMITH.
Professor of Entomology at Rutgers College and State Entomologist of New Jersey.

fifty papers, but a statement of some of the subjects may be of interest as showing the directions in which research work is now being conducted.

At the first session, papers were presented bearing on historical, political and philological subjects, for the Philosophical Society includes these also in its scope. This aspect of its work was indeed emphasized at the recent meeting, as the Henry M. Phillips prize of $2,000 was conferred on Charles H. Burr, Esq., for an essay on the treaty-making power of the United States, and at the dinner, the principal address was made by Professor Moore, who in the usual eulogy of Franklin spoke of his work in diplomacy.

On the second day, the session opened with two papers on the inheritance of feeble-mindedness and epilepsy, by Dr. Goddard and Dr. Weeks, who have obtained results of scientific and practical importance. Dr. Stockard described for the first time experiments on the control of embryonic development, showing that when guinea-pigs are alcoholized, the offspring are greatly af-

fected, and this irrespective of whether it is the male or the female that has been given alcohol. If these experiments are confirmed, it appears that the paternal germ cells may be affected so as to be incapable of producing normal offspring. Dr. Rouse gave an account of his successful attempts to isolate the active agent which produces sarcoma in chickens, which may prove a step forward in the explanation of the cause of cancer. Dr. Vaughan explained how he had split up the protein molecule and obtained a highly poisonous body, Dr. Russell the methods he had used to produce immunity to typhoid fever, and Dr. Carrel the experiments by which he had kept the heart muscle alive outside the body. Papers on botany were presented by Professor Farlow and Dr. Trelease; on paleontology, by Professor Scott and Dr. Walcott; on exploration and discovery by Professor Bingham and General Greely.

The papers in the exact sciences were as important as those in the natural sciences, and were fully as interesting, in spite of the greater difficulty of presenting such subjects before a general audience. Professor Wood gave the evening lecture before the reception, his subject being "The study of nature by invisible light." The lecture was elaborately illustrated and included his curious and beautiful photographs taken with ultra-red light. In a more technical paper, Professor Wood showed the selective reflection of gas molecules, which he has photographed. Professor Webster described his method of measuring the sound transmitted through walls; Professor Magie, the thermal relations of solutions; Dr. Day, the measurement of temperatures up to 750 degrees C., and Dr. Bauer, the results of the magnetic observations made on the yacht *Carnegie*. In astronomy, there was a symposium on stellar spectroscopy. Dr. Campbell explained the work which has been done, largely at the Lick Observatory, on radial velocity; Dr. Pickering, the important work of the Harvard Observatory on photographing the spectra of the stars. Papers of equal importance in chemistry and in other sciences were presented. Altogether they represent a group of contributions to science which will compare favorably with any that could at the present time be presented before any society in any country.

THE FOREIGN-BORN POPULATION OF NEW YORK CITY

THE Census Bureau has given out a preliminary statement of the distribution of the foreign-born population of New York in 1910. The numbers are about 2,700,000 in the state and about 1,900,000 in the city of New York, approaching in the latter case one half of the total population, and far exceeding this, if the native children born to foreign parents are included. In both New England and the middle states considerably more than half the population is of foreign parentage and the proportion is increasing with great rapidity. The distribution of the foreign-born population is of special interest. It is well known that the Russians, Italians and Austrians have been increasing far more rapidly than the Germans and Irish, but the actual figures are truly surprising. In 1850 forty-three per cent. of the foreign-born population of the United States was Irish, fourteen per cent. English, three per cent. Scotch, twenty-six per cent. German, seven per cent. Canadian, leaving only seven per cent. from all other nations. In 1900 the percentage of Germans had remained about the same, the percentage of Irish had decreased by about sixteen, and the influx from Russia, Italy and Austria Hungary had become noticeable. In the figures now given out for New York City, we find that there are 45,000 fewer Germans and 22,500 fewer Irish than there were ten years ago. On the other hand, the Italian population shows an increase of nearly 200,000, being now 340,000. New York City is now an Italian city nearly as

large as Rome and bids fair to exceed it in the course of the coming decennium. The Austria-Hungarian population has more than doubled, having increased from about 120,000 to 267,000. Greatest of all is the Russian increase, from 180,000 in 1890 to 484,000 in 1910. A citizen of New York City on being asked whether there was a foreign quarter in the city replied that there was a foreign three-quarters; and this is not far from correct.

SCIENTIFIC ITEMS

We record with regret the death of Dr. Paul C. Freer, director of the U. S. Government Scientific Bureau in the Philippines, and distinguished for his work in chemistry; of the Rev. George William Knox, professor of philosophy and the history of religion in the Union Theological Seminary, and of Miss Nettie M. Stevens, associate in experimental morphology in Bryn Mawr College.

Dr. John Grier Hibben, previously Stuart professor of philosophy, has been installed as president of Princeton University.—Commemoration day will be observed by the University of Glasgow on June 25, when Professor F. O. Bower, F.R.S., will deliver an oration on "Sir Joseph Hooker."—The Aero Club of Washington has held a field day in commemoration of the anniversary of Secretary Langley's first aerodrome flight on May 6, 1896.—The letters of the late Professor William James are being collected for biographical purposes. Those who have such letters are requested to communicate with Mr. Henry James, Jr., 95 Irving Street, Cambridge, Mass.

At the meeting of the National Academy of Sciences, held in Washington on April 18, new members were elected as follows: R. W. Wood, professor of experimental physics at the Johns Hopkins University; Harry Fielding Reid, professor of geological physics at the Johns Hopkins University; David White, geologist, U. S. Geological Survey; Roland Thaxter, professor of cryptogamic botany at Harvard University; Chas. B. Davenport, director of the Station for Experimental Evolution, Cold Spring Harbor, N. Y.; W. M. Wheeler, professor of economic entomology at Harvard University; John J. Abel, professor of pharmacology at the Johns Hopkins University; S. J. Meltzer, head of the department of physiology and pharmacology of the Rockefeller Institute for Medical Research.

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